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(12) **United States Patent**  
**Civelli et al.**

(10) **Patent No.: US 6,437,114 B1**  
(45) **Date of Patent: \*Aug. 20, 2002**

(54) **HUMAN DOPAMINE RECEPTOR AND USES**

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(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

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(51) **Int. Cl.**<sup>7</sup> ..... **C12N 15/12**

(52) **U.S. Cl.** ..... **536/23.5**; 435/69.1; 435/252.3; 435/320.1

(58) **Field of Search** ..... 435/69.1, 252.3, 435/320.1; 536/23.5

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(57) **ABSTRACT**

The present invention is directed toward the isolation, characterization and pharmacological use of the human D4 dopamine receptor. The nucleotide sequence of the gene corresponding to this receptor and allelic variant thereof are provided by the invention. The invention also includes recombinant eukaryotic expression constructs capable of expressing the human D4 dopamine receptor in cultures of transformed eukaryotic cells. The invention provides cultures of transformed eukaryotic cells which synthesize the human D4 dopamine receptor, and methods for characterizing novel psychotropic compounds using such cultures.

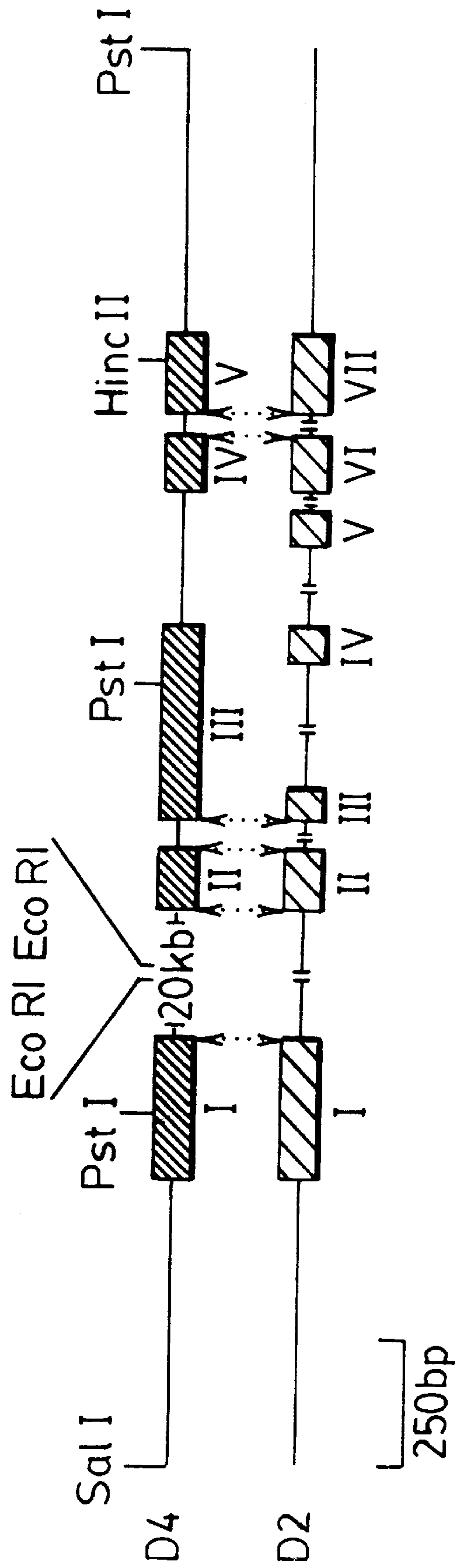
**4 Claims, 20 Drawing Sheets**



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FIG. 1





**Figure 2A**

5' - CGGGGGCGGGACCAGGGTCCGGCCGGGGCGTGCCCC  
GGGGAGGGACTCCCCGGCTTGCCCCCGGCGTTGTCCGCGGTG  
CTCAGCGCCCGCCCGGGCGCGCC<sup>+1</sup> ATG GGG AAC CGC AGC  
MET GLY ASN ARG SER  
48  
ACC GCG GAC GCG GAC GGG CTG CTG GCT GGG CGC  
THR ALA ASP ALA ASP GLY LEU LEU ALA GLY ARG  
GGG CGG GCC GCG GGG GCA TCT GCG GGG GCA TCT  
GLY PRO ALA ALA GLY ALA SER ALA GLY ALA SER  
114  
GCG GGG CTG GCT GGG CAG GGC GCG GCG GCG CTG  
ALA GLY LEU ALA GLY GLN GLY ALA ALA ALA LEU  
GTG GGG GGC GTG CTG CTC ATC GGC GCG GTG CTC  
VAL GLY GLY VAL LEU LEU ILE GLY ALA VAL LEU  
180  
GCG GGG AAC TCG CTC GTG TGC GTG AGC GTG GCC  
ALA GLY ASN SER LEU VAL CYS VAL SER VAL ALA  
ACC GAG CGC GCC CTG CAG ACG CCC ACC AAC TCC  
THR GLU ARG ALA LEU GLN THR PRO THR ASN SER  
246  
TTC ATC GTG AGC CTG GCG GCC GCC GAC CTC CTC  
PHE ILE VAL SER LEU ALA ALA ALA ASP LEU LEU  
CTC GCT CTC CTG GTG CTG CCG CTC TTC GTC TAC  
LEU ALA LEU LEU VAL LEU PRO LEU PHE VAL TYR  
TCC GAG GTGAGCCGCGTCCGGCCGCA.....  
SER GLU  
...CCTGTGGTGTGCGCCGCGCAG GTC CAG GGT GGC GCG  
VAL GLN GLY GLY ALA  
333  
TGG CTG CTG AGC CCC CGC CTG TGC GAC GCC CTC  
TRP LEU LEU SER PRO ARG LEU CYS ASP ALA LEU

**Figure 2B**

ATG GCC ATG GAC GTC ATG CTG TGC ACC GCC TCC  
 MET ALA MET ASP VAL MET LEU CYS THR ALA SER  
 398

ATC TTC AAC CTG TGC GCC ATC AGC GTG GAC AG  
 ILE PHE ASN LEU CYS ALA ILE SER VAL ASP ARG

GTGCGCCGCCCTCCCCGCCCGCGCCCCGGCGCCCCCGCGCCCC

GCCCGCCGCCCTCACCGCGGCCTGTGCGCTGTCCGGCGCCCCC

TCGGCGCTCCCCGCAG G TTC GTG GCC GTG GCC GTG  
 PHE VAL ALA VAL ALA VAL  
 450

CCG CTG CGC TAC AAC CGG CAG GGT GGG AGC CGC  
 PRO LEU ARG TYR ASN ARG GLN GLY GLY SER ARG

CGG CAG CTG CTG CTC ARC GGC GCC ACG TGG CTG  
 ARG GLN LEU LEU LEU ILE GLY ALA THR TRP LEU  
 □ 516

CTG TCC GCG GCG GTG GCG GCG CCC GTA CTG TGC  
 LEU SER ALA ALA VAL ALA ALA PRO VAL LEU CYS

GGC	CTC	AAC	GAC	GTG	CGC	GGC	CGC	GAC	CCC	GCC
GLY	LEU	ASN	ASP	VAL	ARG	GLY	ARG	ASP	PRO	ALA

582

GTG	TGC	CGC	CTG	GAG	GAC	CGC	GAC	TAC	GTG	GTC
VAL	CYS	ARG	LEU	GLU	ASP	ARG	ASP	TYR	VAL	VAL

TAC	TCG	TCC	GTG	TGC	TCC	TTC	TTC	CTA	CCC	TGC
TYR	SER	SER	VAL	CYS	SER	PHE	PHE	LEU	PRO	CYS

648

CCG	CTC	ATG	CTG	CTG	CTG	TAC	TGG	GCC	ACG	TTC
PRO	LEU	MET	LEU	LEU	LEU	TYR	TRP	ALA	THR	PHE

CGC	GGC	CTG	CAG	CGC	TGG	GAG	GTG	GCA	CGT	CGC
ARG	GLY	LEU	GLN	ARG	TRP	GLU	VAL	ALA	ARG	ARG

714

GCC	AAG	CTG	CAC	GGC	CGC	GCG	CCC	CGC	CGA	CCC
ALA	LYS	LEU	HIS	GLY	ARG	ALA	PRO	ARG	ARG	PRO



**Figure 2C**

AGC GGC CCT GGC CCG CCT TCC CCC ACG CCA CCC  
 SER GLY PRO GLY PRO PRO SER PRO THR PRO PRO  
 780

GCG CCC CGC CTC CCC CAG GAC CCC TGC GGC CCC  
 ALA PRO ARG LEU PRO GLN ASP PRO CYS GLY PRO

GAC TGT GCG CCC CCC GCG CCC GGC CT TCCCGGG  
 ASP CYS ALA PRO PRO ALA PRO GLY LEU

GTCCCTGCGGCC.....CCTGTGCGCCCCCGCGCCCGGCCT

CCCCCAGGACCCCTGCGGCCCGACTGTGCGCCCCCGCGCCC  
 834

GGCCT C CCC CCG GAC CCC TGC GGC TCC AAC TGT  
 PRO PRO ASP PRO CYS GLY SER ASN CYS

GCT CCC CCC GAC GCC GTC AGA GCC GCC GCG CTC  
 ALA PRO PRO ASP ALA VAL ARG ALA ALA ALA LEU  
 900

CCA CCC CAG ACT CCA CCG CAG ACC CGC AGG AGG  
 PRO PRO GLN THR PRO PRO GLN THR ARG ARG ARG

CGG CGT GCC AAG ATC ACC GGC CGG GAG CGC AAG  
 ARG ARG ALA LYS ILE THR GLY ARG GLU ARG LYS

GCC ATG AGG GTC CTG CCG GTG GTG GTC G GTGG  
 ALA MET ARG VAL LEU PRO VAL VAL VAL

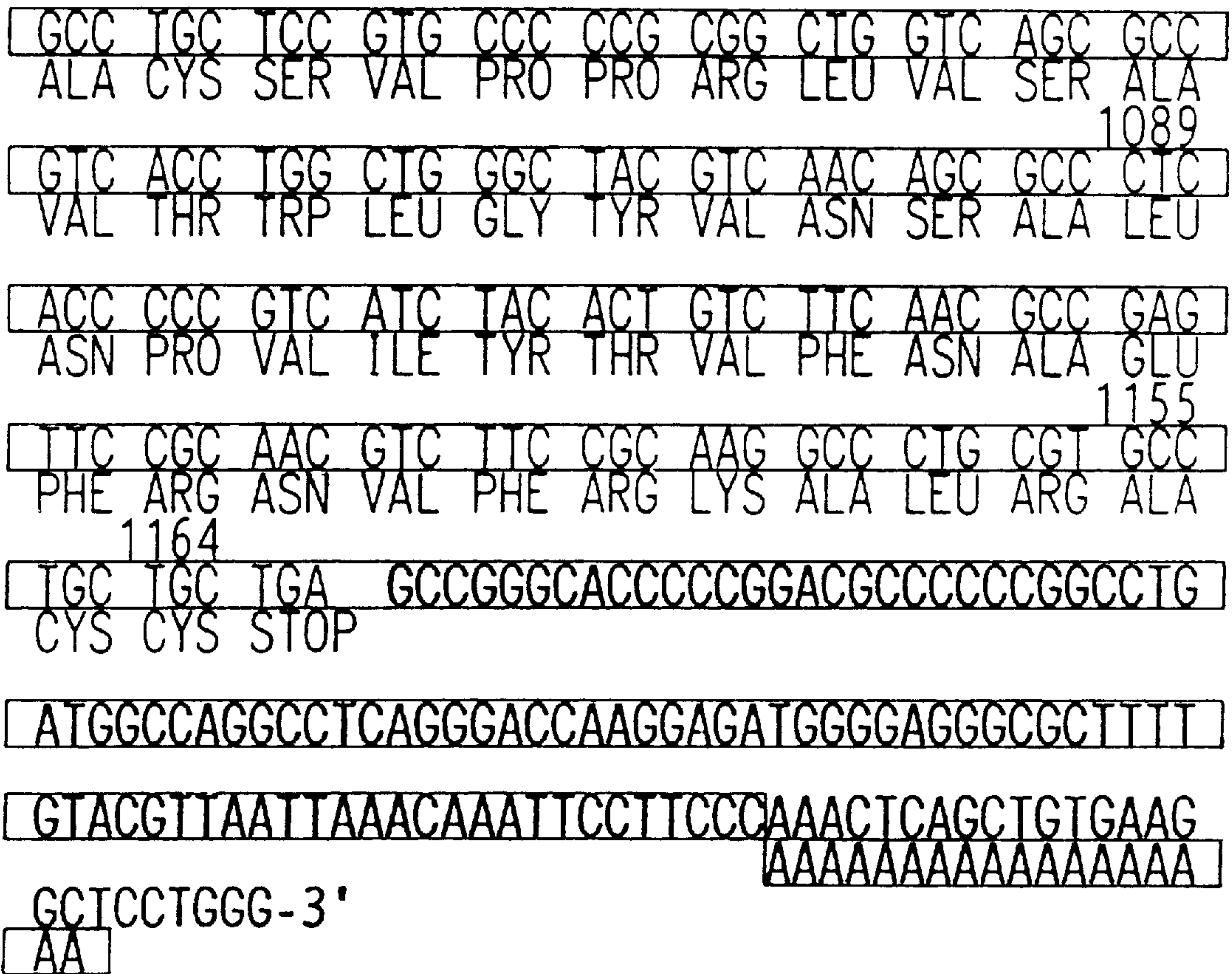
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GAGGCCGGCTGGGCGGGGGGCGCTAACGCGGCTCTCGGCGCCC

CCAG GG GCC TTC CTG CTG TGC TGG ACG CCC TTC  
 GLY ALA PHE LEU LEU CYS TRP THR PRO PHE  
 1023

TTC GTG GTG CAC ATC ACG CAG GCG CTG TGT CCT  
 PHE VAL VAL HIS ILE THR GLN ALA LEU CYS PRO

**Figure 2D**



**FIG. 3**

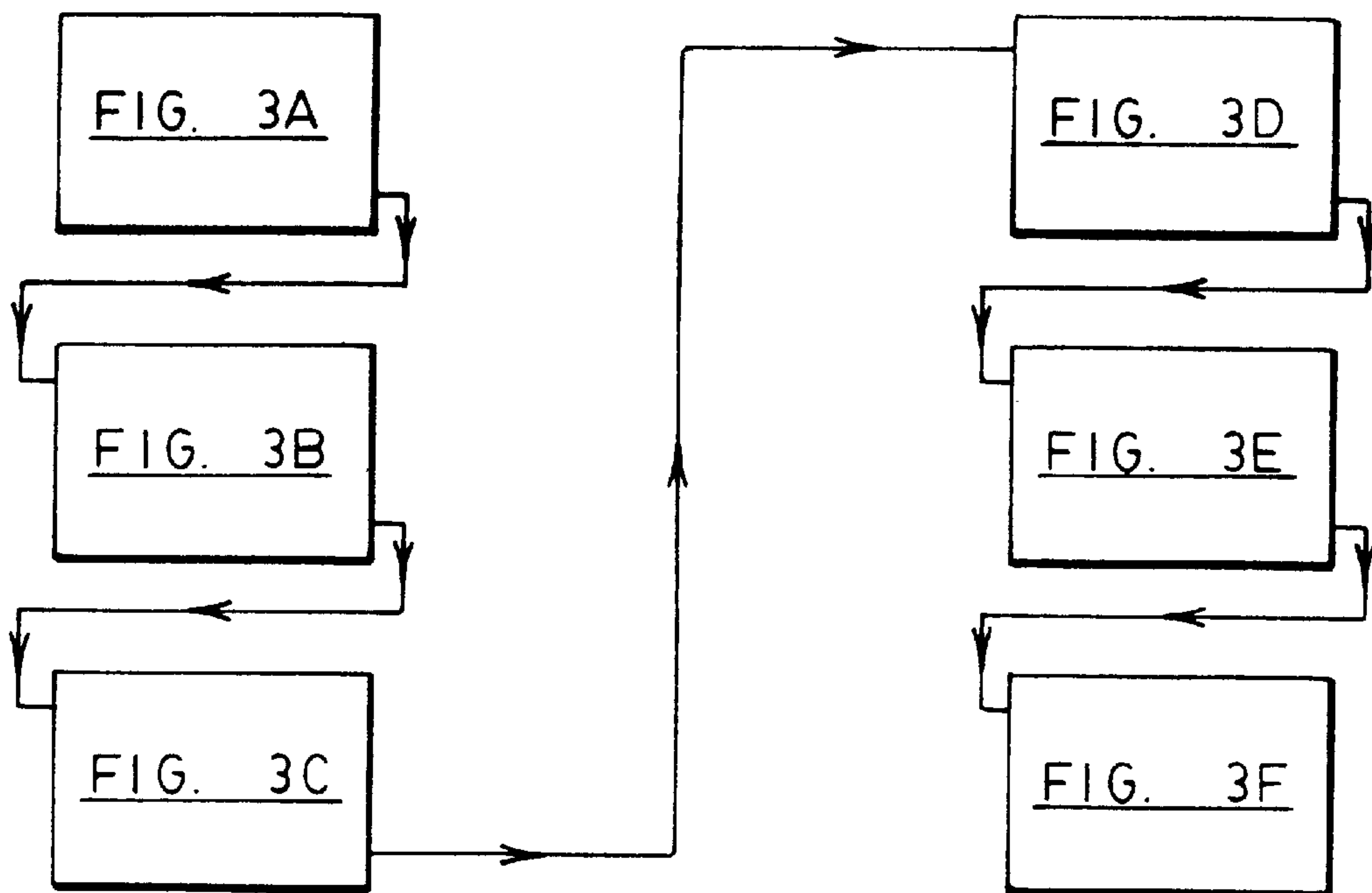


FIG. 3A

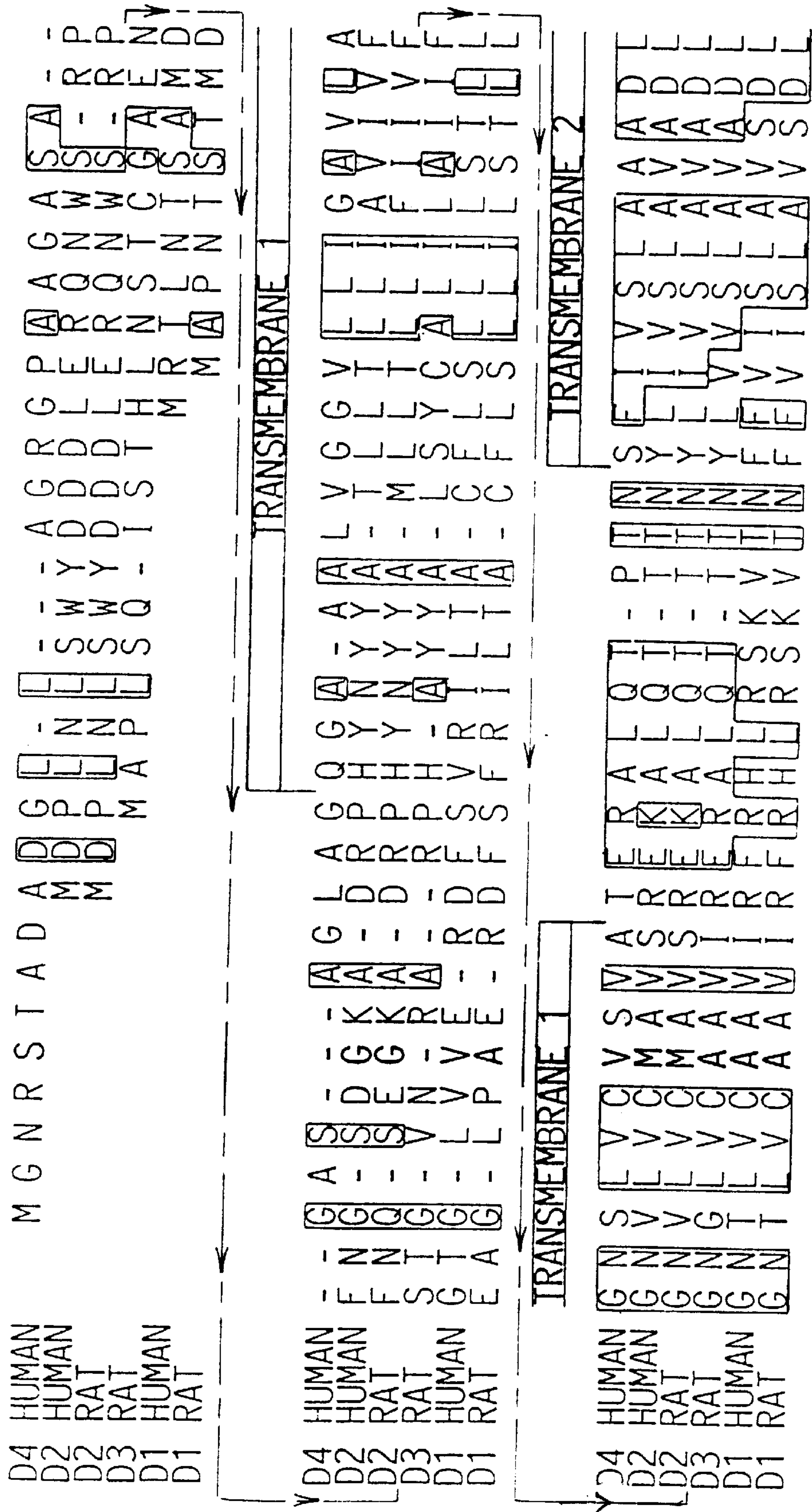
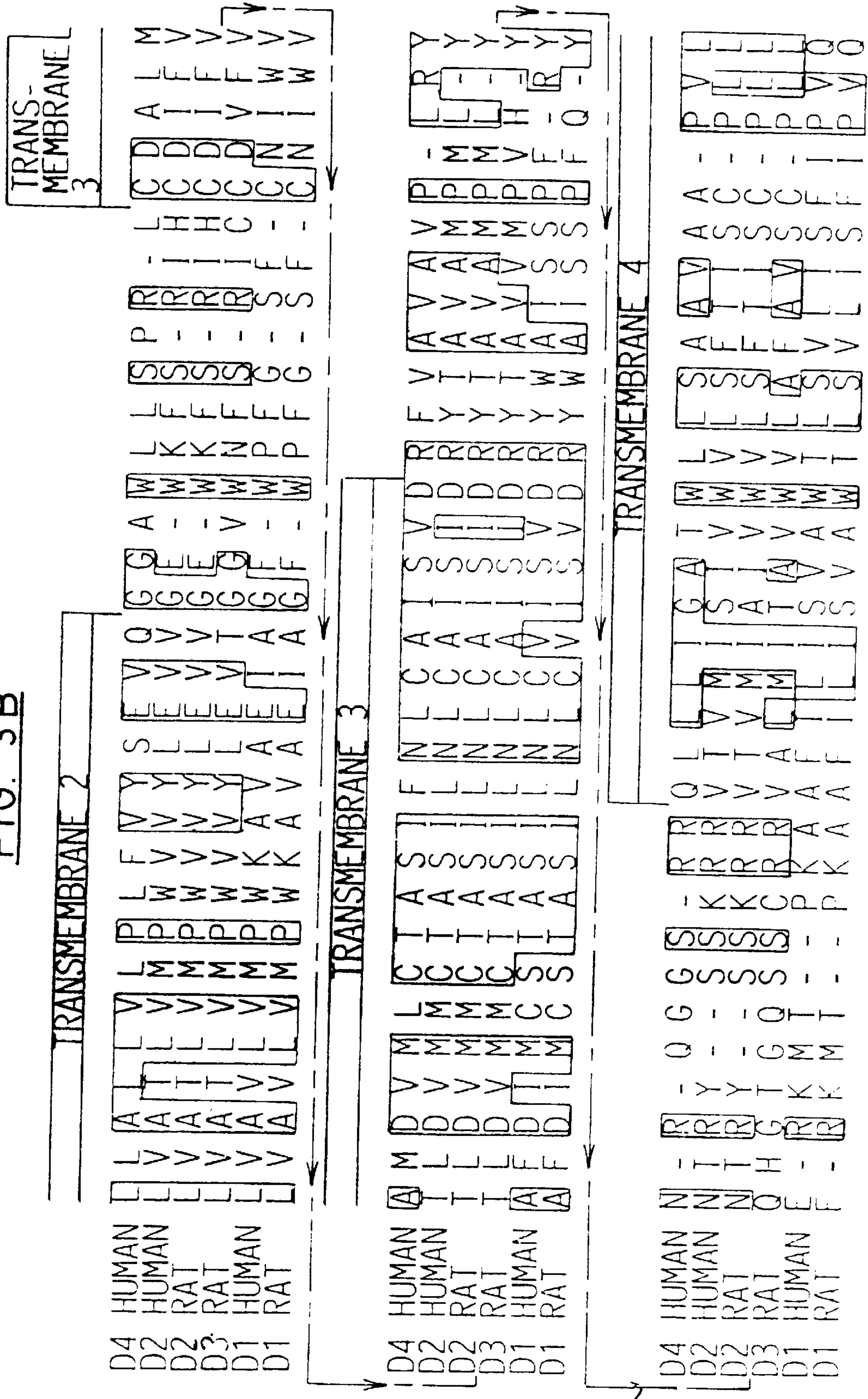




FIG. 3B



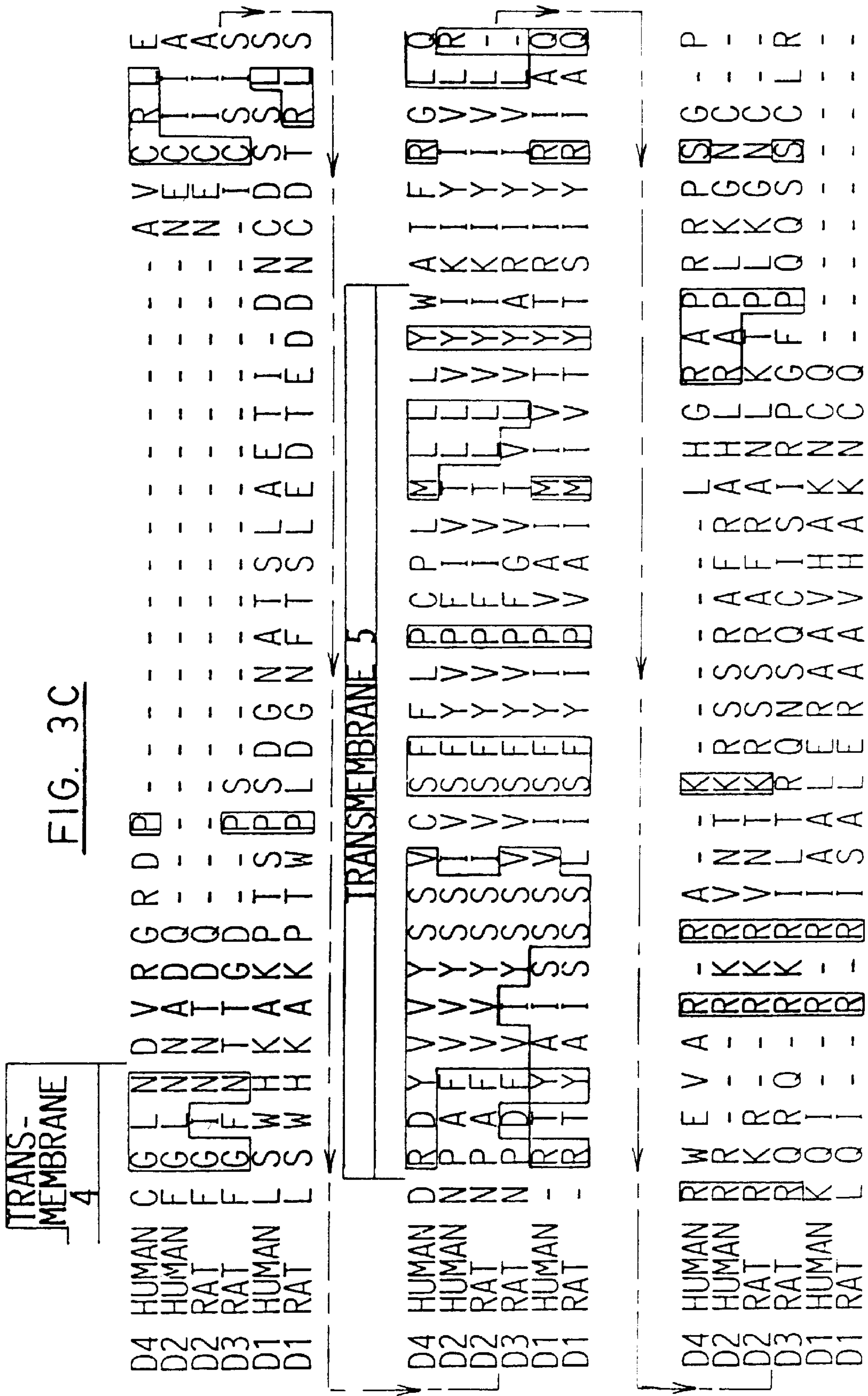




FIG. 3D

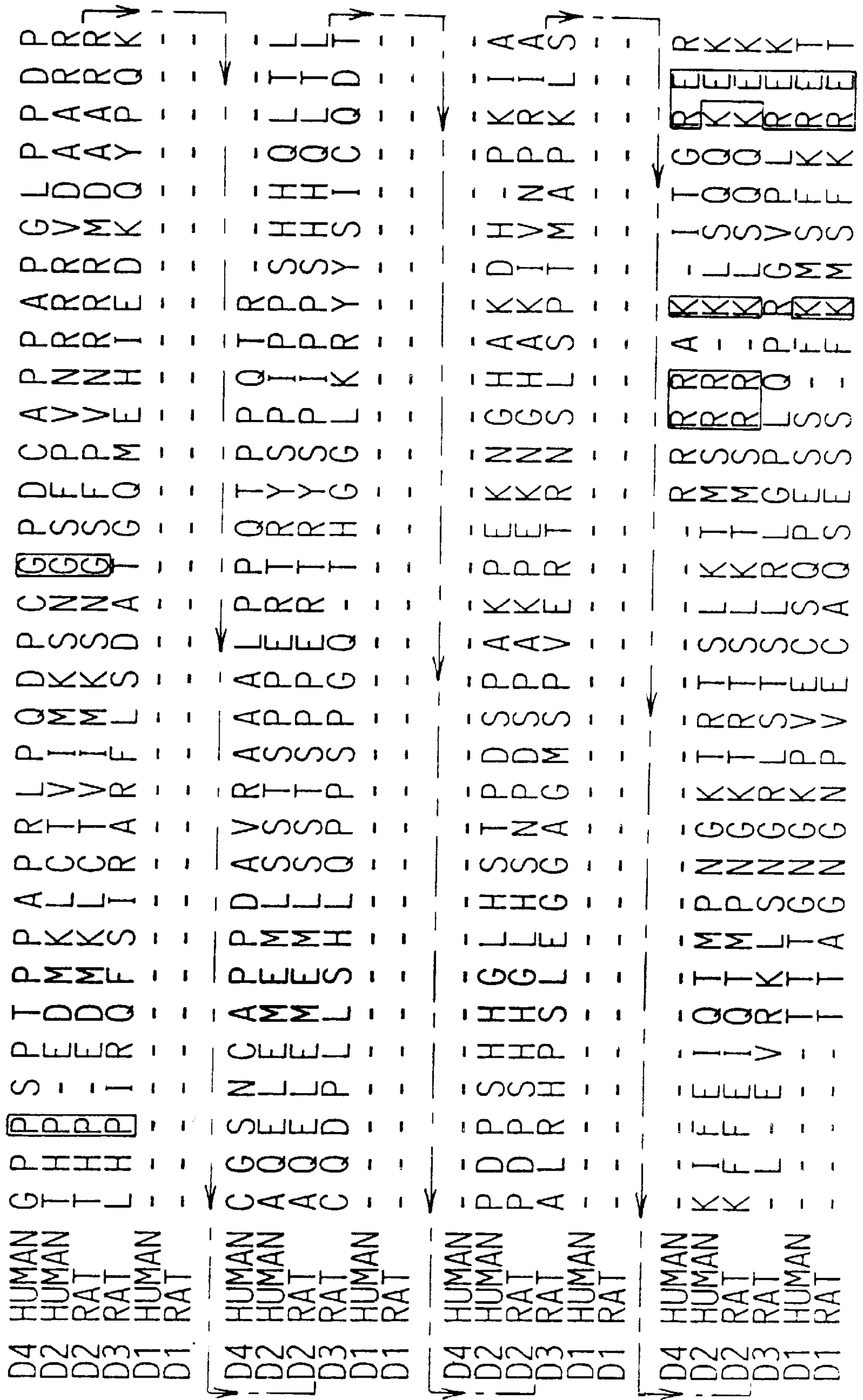


FIG. 3E

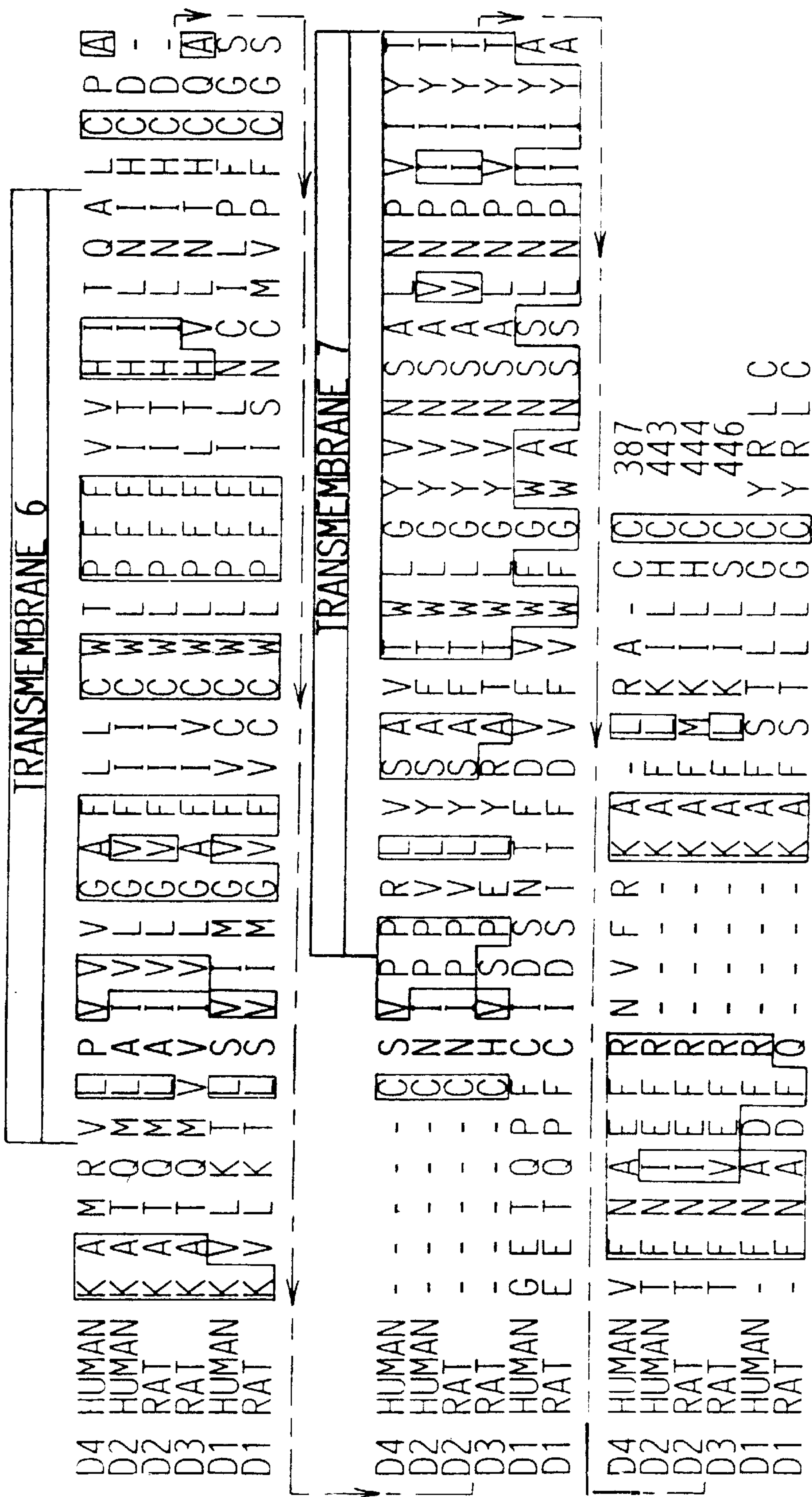




FIG. 3F

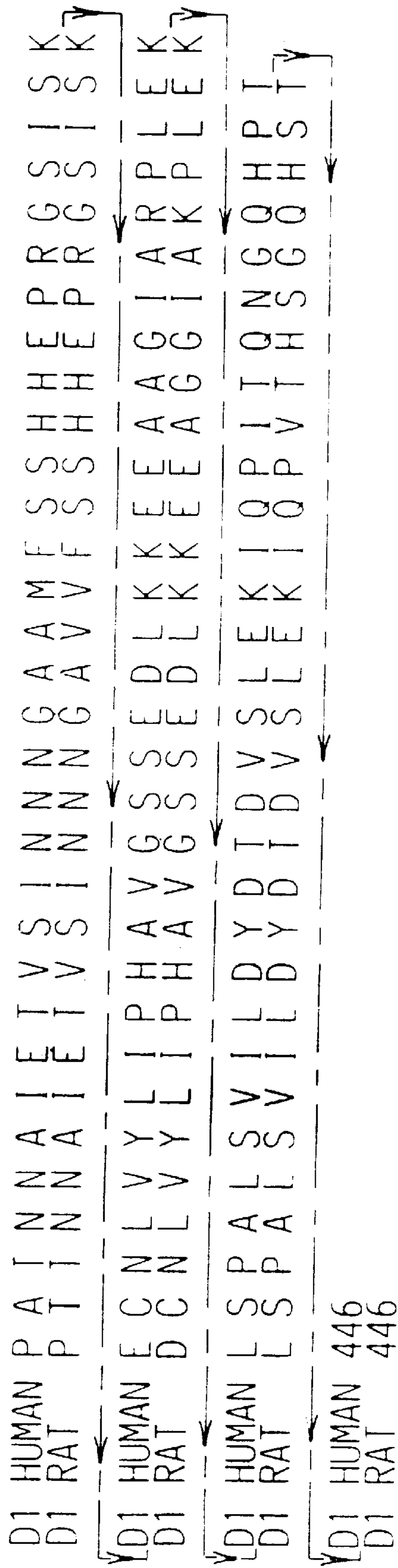


FIG. 4A

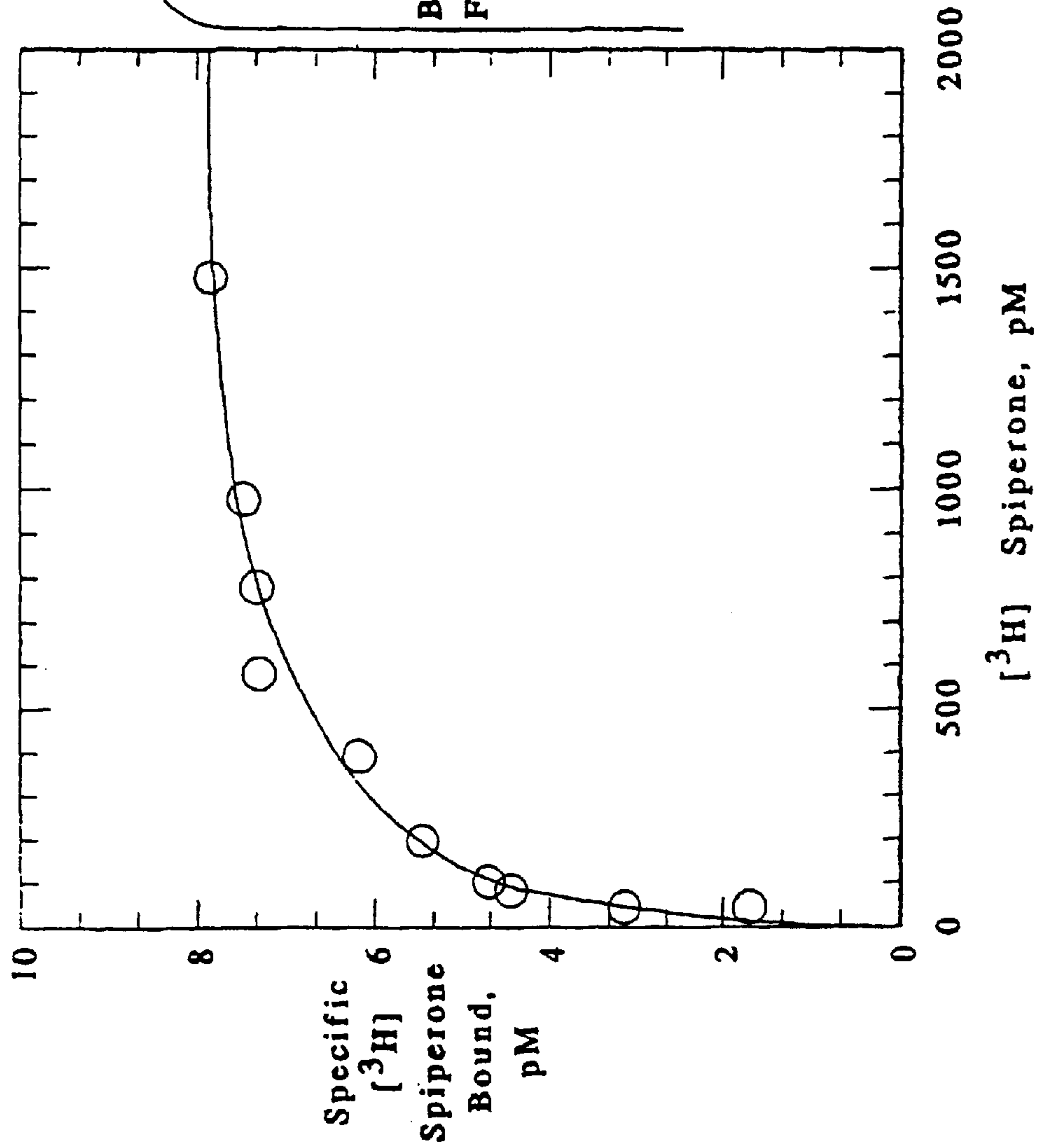
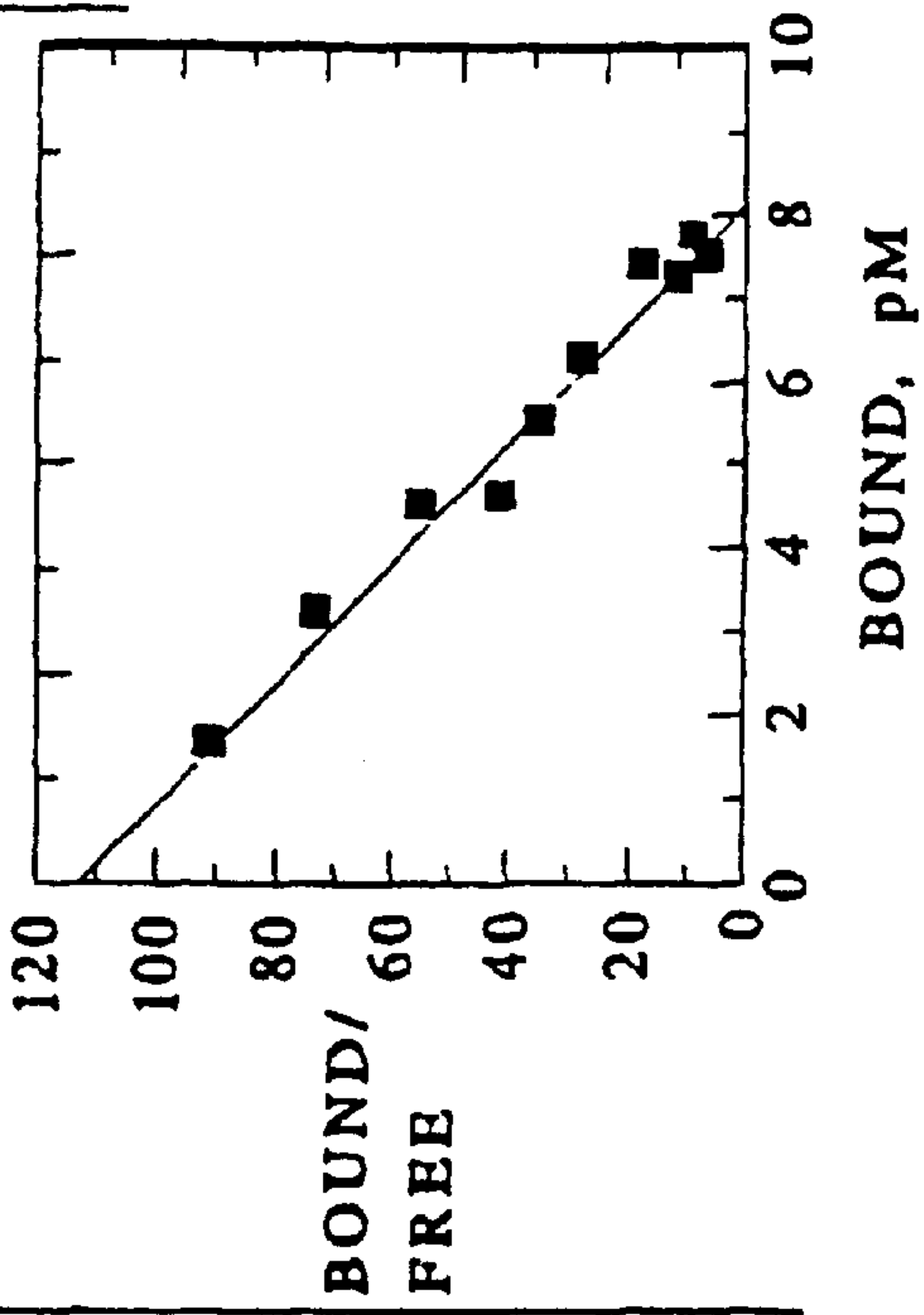


FIG. 4B





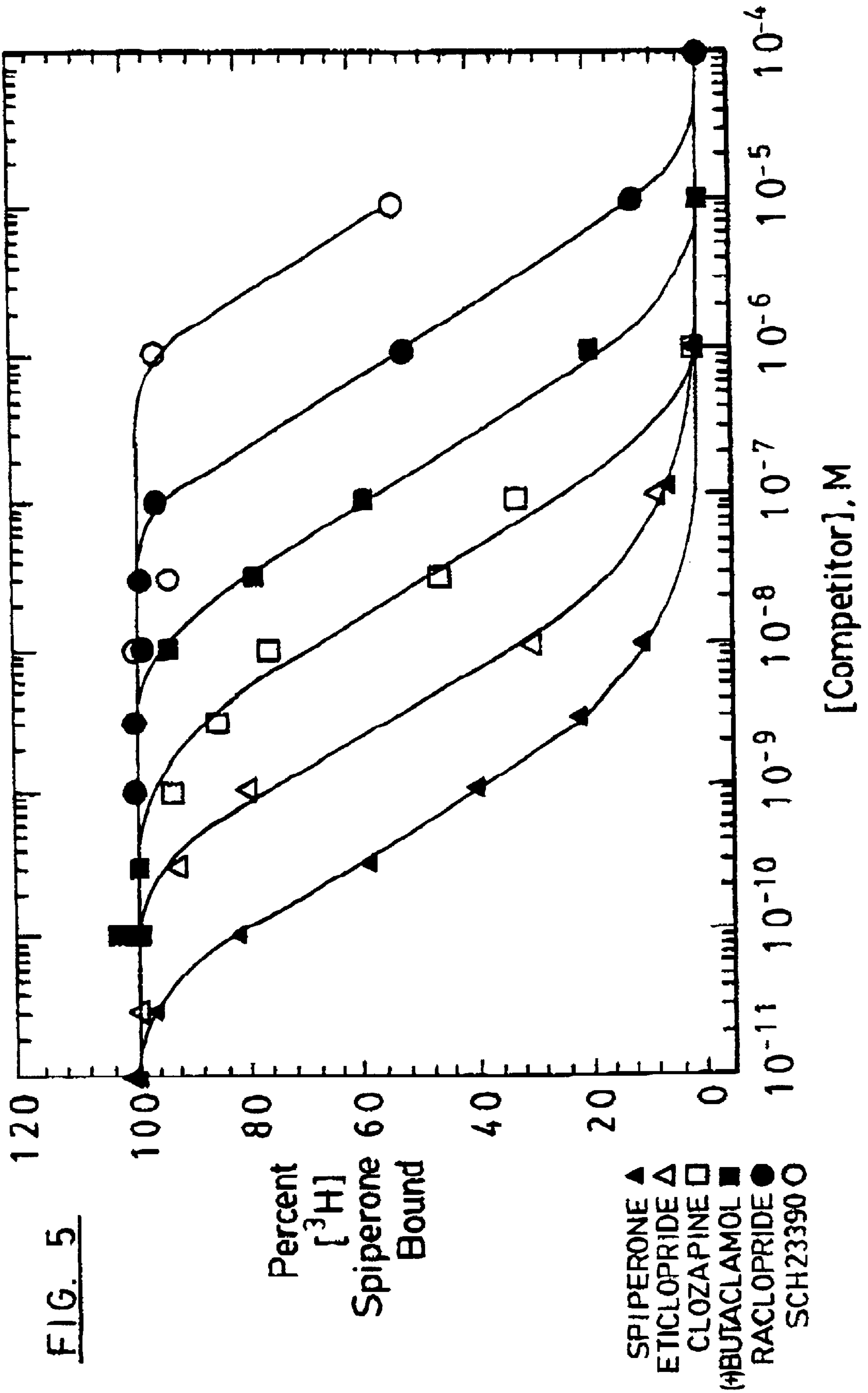


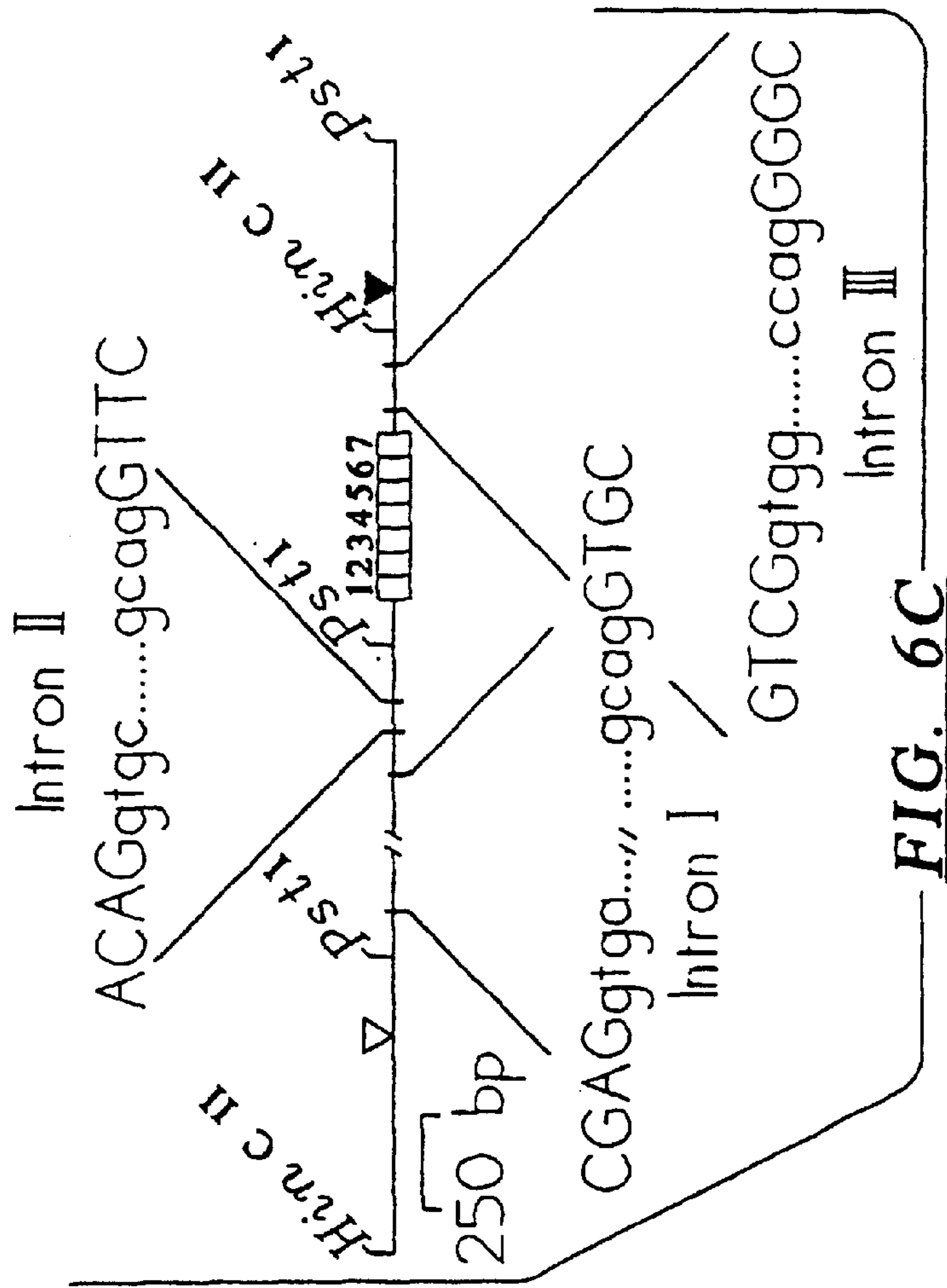
FIG. 6A

D4 2...	ACG CC	A	CCC	GCG	CCC	CGC	CTC	CCC	CAG	GAC	CCC	TGC	GGC	CCC	GAC	TGT	GCG	CC
D4 4...	ACG CC	A	CCC	GCG	CCC	CGC	CTC	CCC	CAG	GAC	CCC	TGC	GGC	CCC	GAC	TGT	GCG	CC
D4 7...	ACG CC	A	CCC	GCG	CCC	CGC	CTC	CCC	CAG	GAC	CCC	TGC	GGC	CCC	GAC	TGT	GCG	CC
REPEAT 2		C	CCC	GCG	CCC	GGC	CTT	CCC	CGG	GGT	CCC	TGC	GGC	CCC	GAC	TGT	GCG	CC
		C	CCC	GCG	CCC	GGC	CTT	CCC	CGG	GGT	CCC	TGC	GGC	CCC	GAC	TGT	GCG	CC
REPEAT 3		C	GCC	GCG	CCC	GGC	CTC	CCC	CCG	GAC	CCC	TGC	GGC	CCC	GAC	TGT	GCG	CC
REPEAT 4		C	CCC	GCG	CCC	GGC	CTC	CCC	CAG	GAC	CCC	TGC	GGC	CCC	GAC	TGT	GCG	CC
REPEAT 5		C	CCC	GCG	CCC	GGC	CTT	CCC	CGG	GGT	CCC	TGC	GGC	CCC	GAC	TGT	GCG	CC
REPEAT 6		C	CC	GCG	CCC	GGC	CTC	CCC	CAG	GAC	CCC	TGC	GGC	CCC	GAC	TGT	GCG	CC
		C	CCC	GCG	CCC	GGC	CTC	CCC	CAG	GAC	CCC	TGC	GGC	CCC	GAC	TGT	GCG	CC
REPEAT 7		C	CCC	GCG	CCC	GGC	CTC	CCC	CCG	GAC	CCC	TGC	GGC	TCC	AAC	TGT	GCT	CCC
		C	CCC	GCG	CCC	GGC	CTC	CCC	CCG	GAC	CCC	TGC	GGC	TCC	AAC	TGT	GCT	CCC
		C	CCC	GCG	CCC	GGC	CTC	CCC	CCG	GAC	CCC	TGC	GGC	TCC	AAC	TGT	GCT	CCC



**FIG. 6B**

D4.2	.....	TPAPRL	PODPCGPD	CAP
D4.4	.....	TPAPRL	PODPCGPD	CAP
D4.7	.....	TPAPRL	PODPCGPD	CAP
REPEAT 2	-----	PAPGL	PRGPCGP	DCAP
REPEAT 3	-----	AAPGL	PPDPCGP	DCAP
REPEAT 4	-----	PAPGL	PODPCGP	DCAP
REPEAT 5	-----	PAPGL	PRGPCGP	DCAP
REPEAT 6	-----	PAPGL	PODPCGP	DCAP
REPEAT 7	-----	PAPGL	PPDPCGS	NCAPDA
		PAPGL	PPDPCGS	NCAPDA
		PAPGL	PPDPCGS	NCAPDA



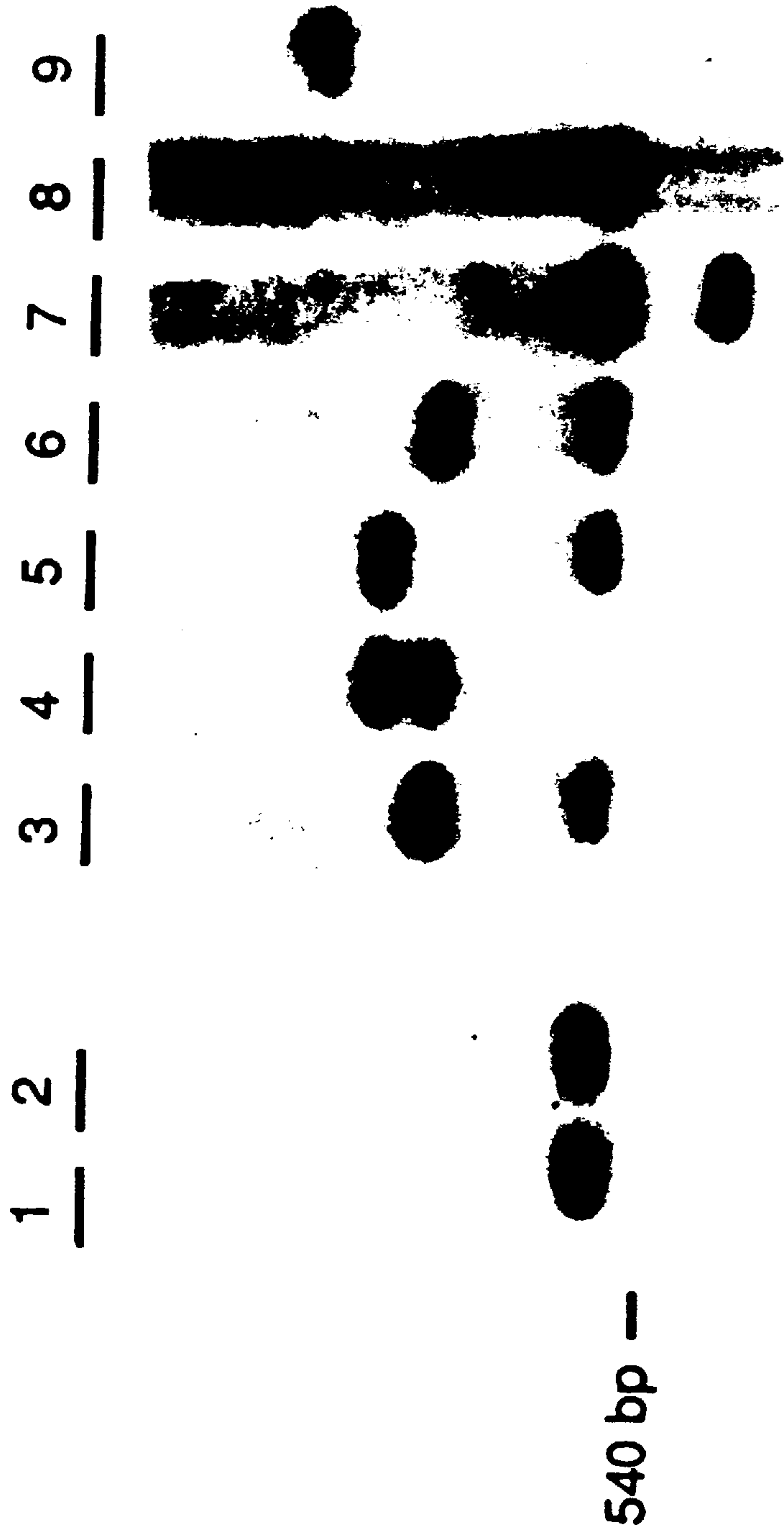
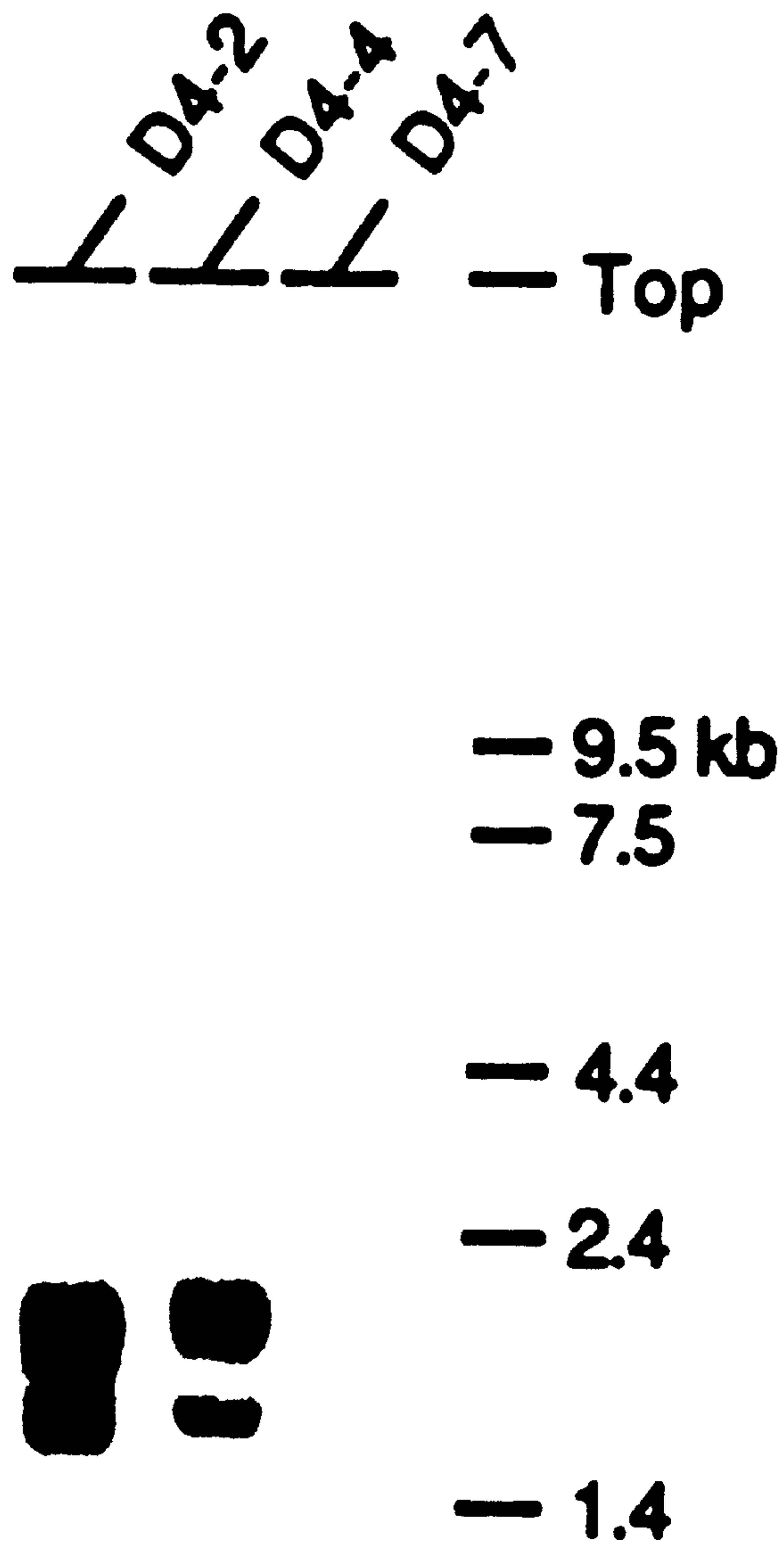


FIG. 7



*FIG. 8*



FIG. 9A

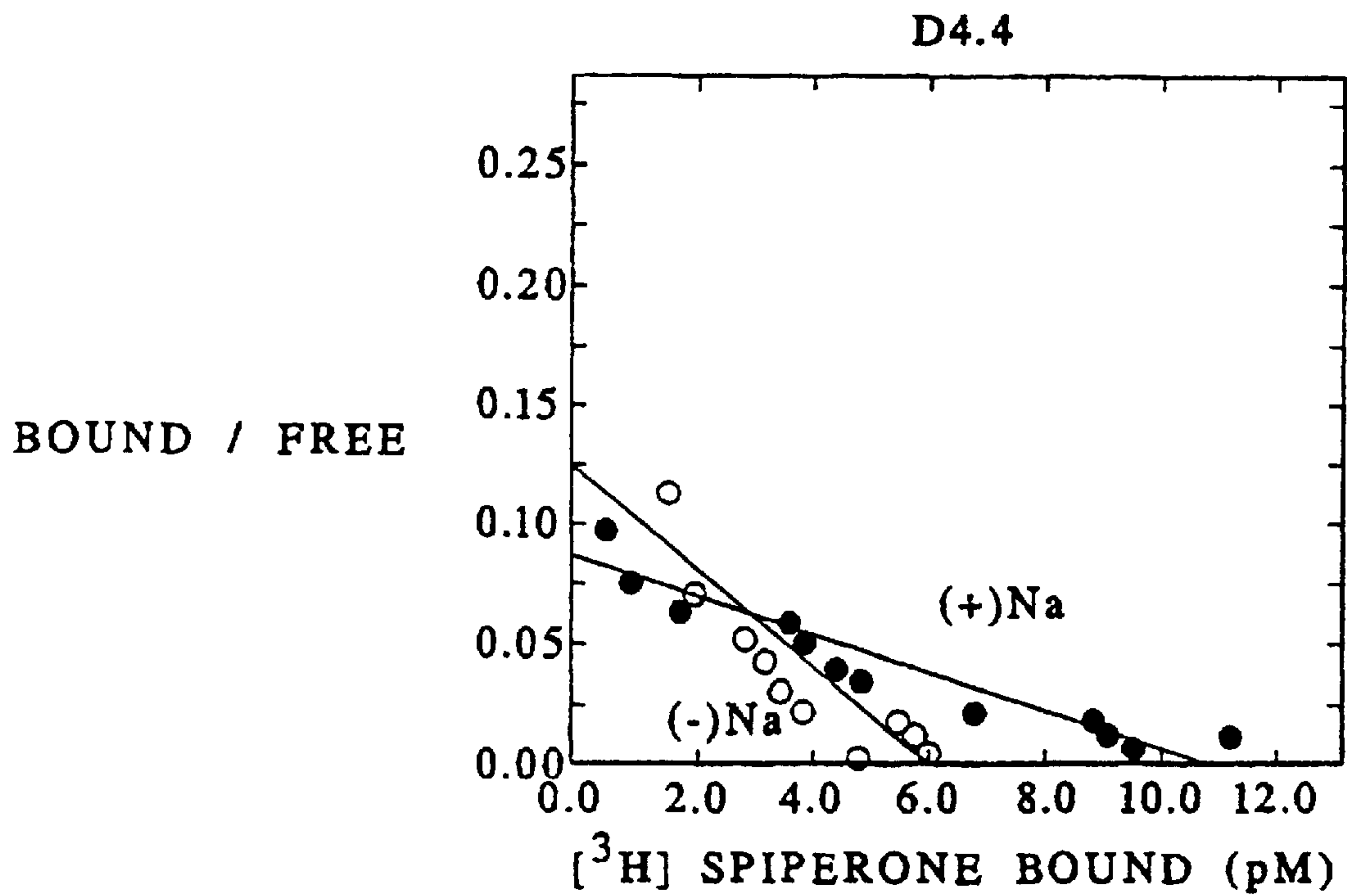
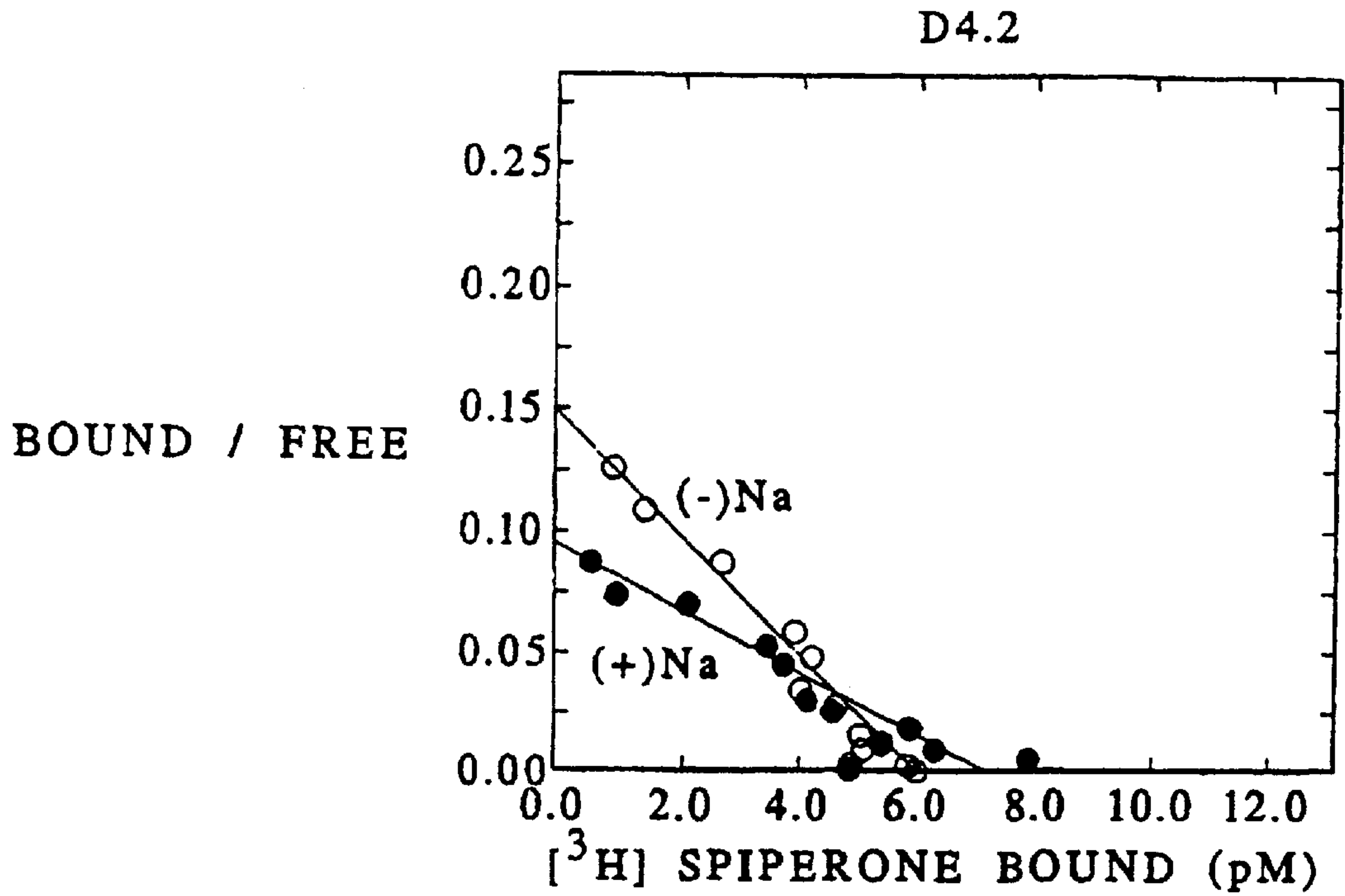
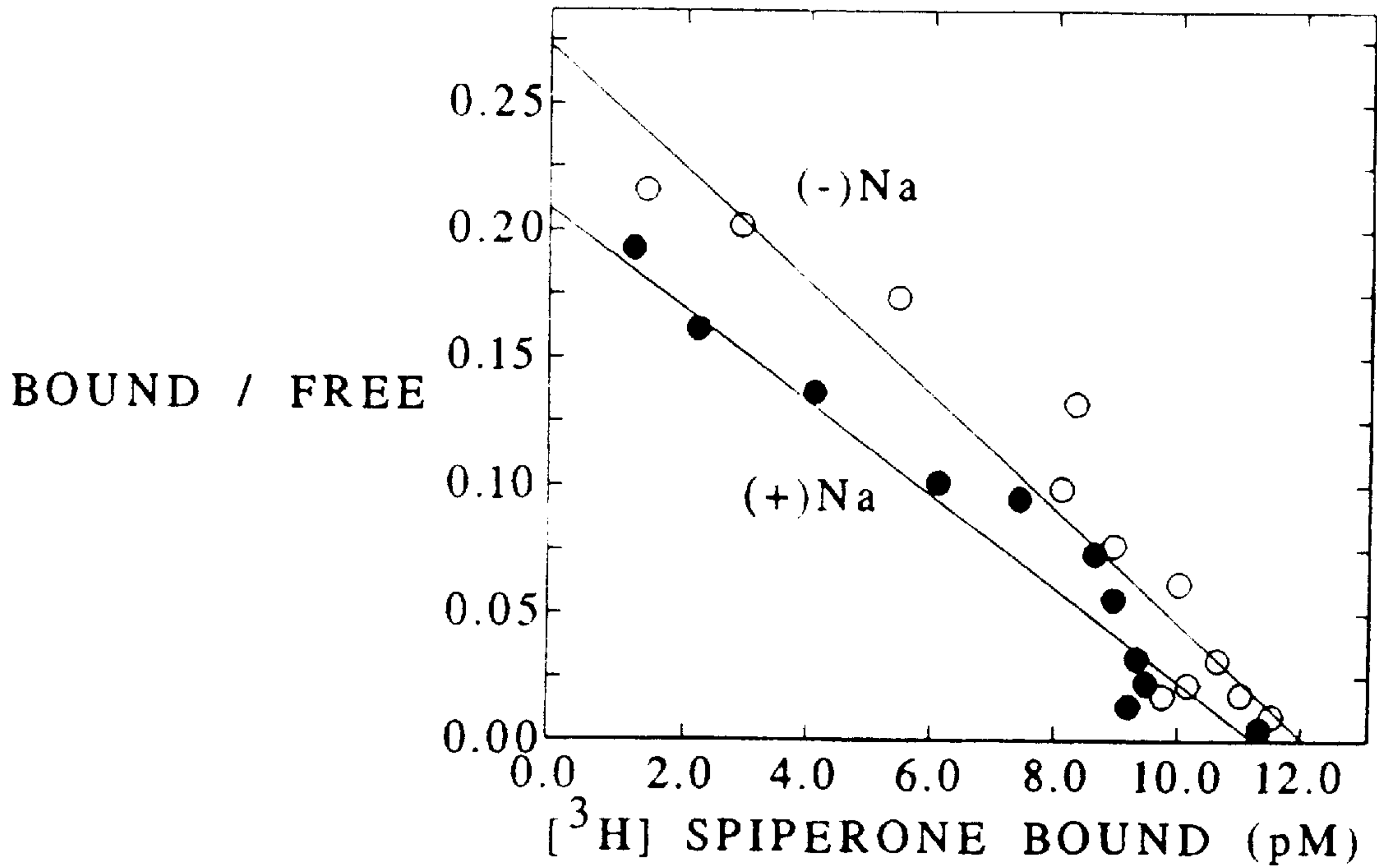


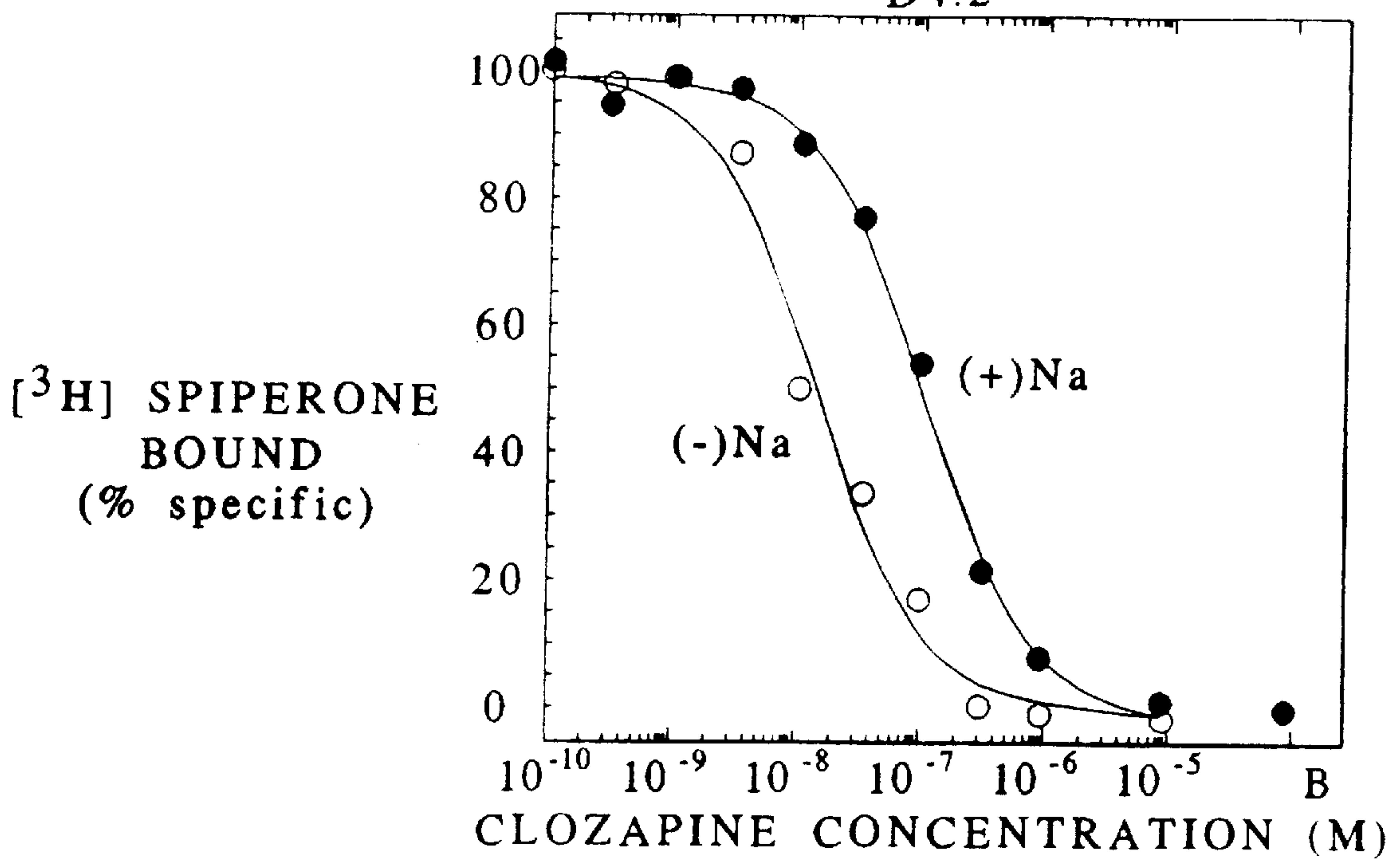
FIG. 9B

**FIG. 9C**

D4.7

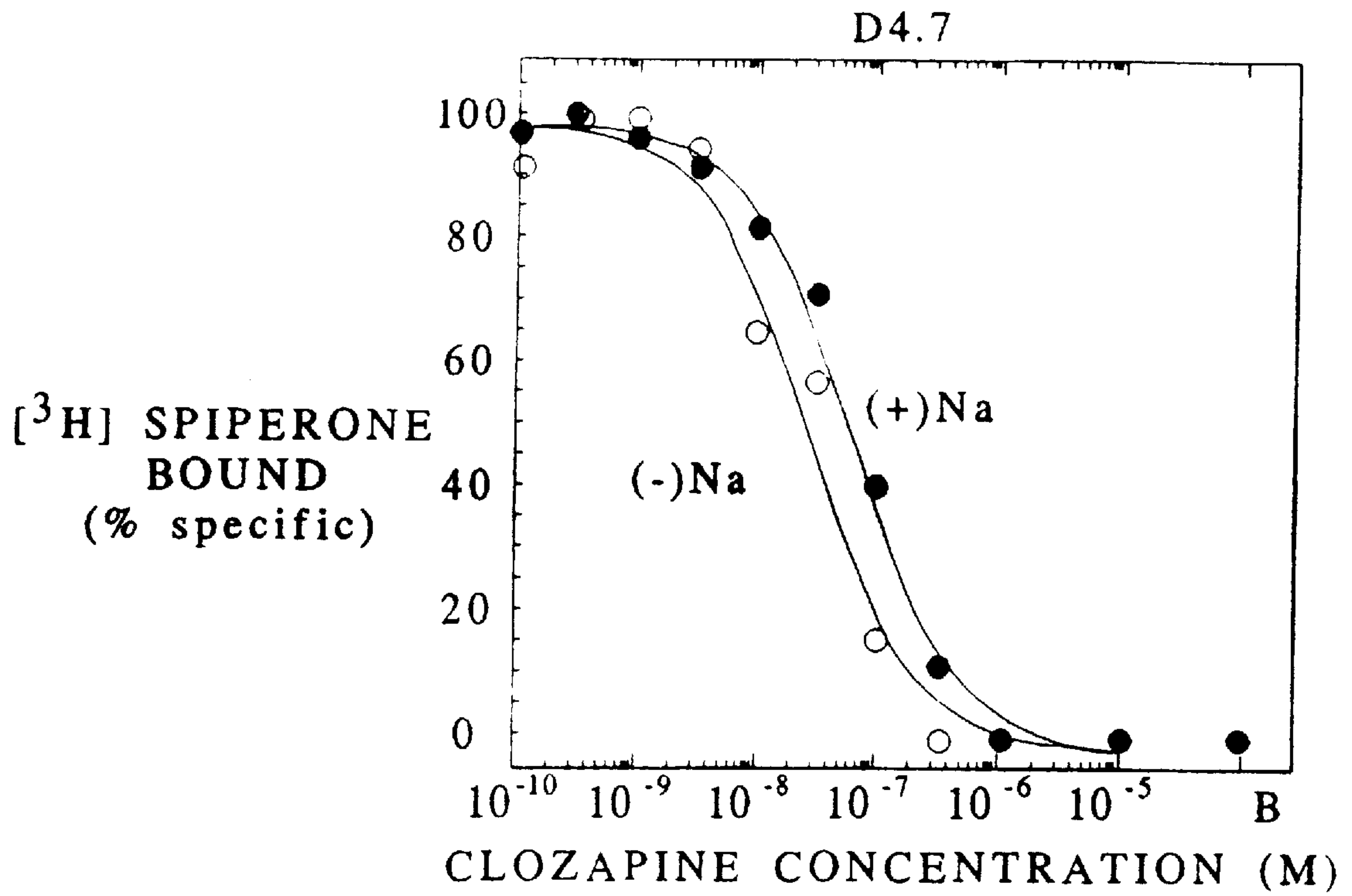
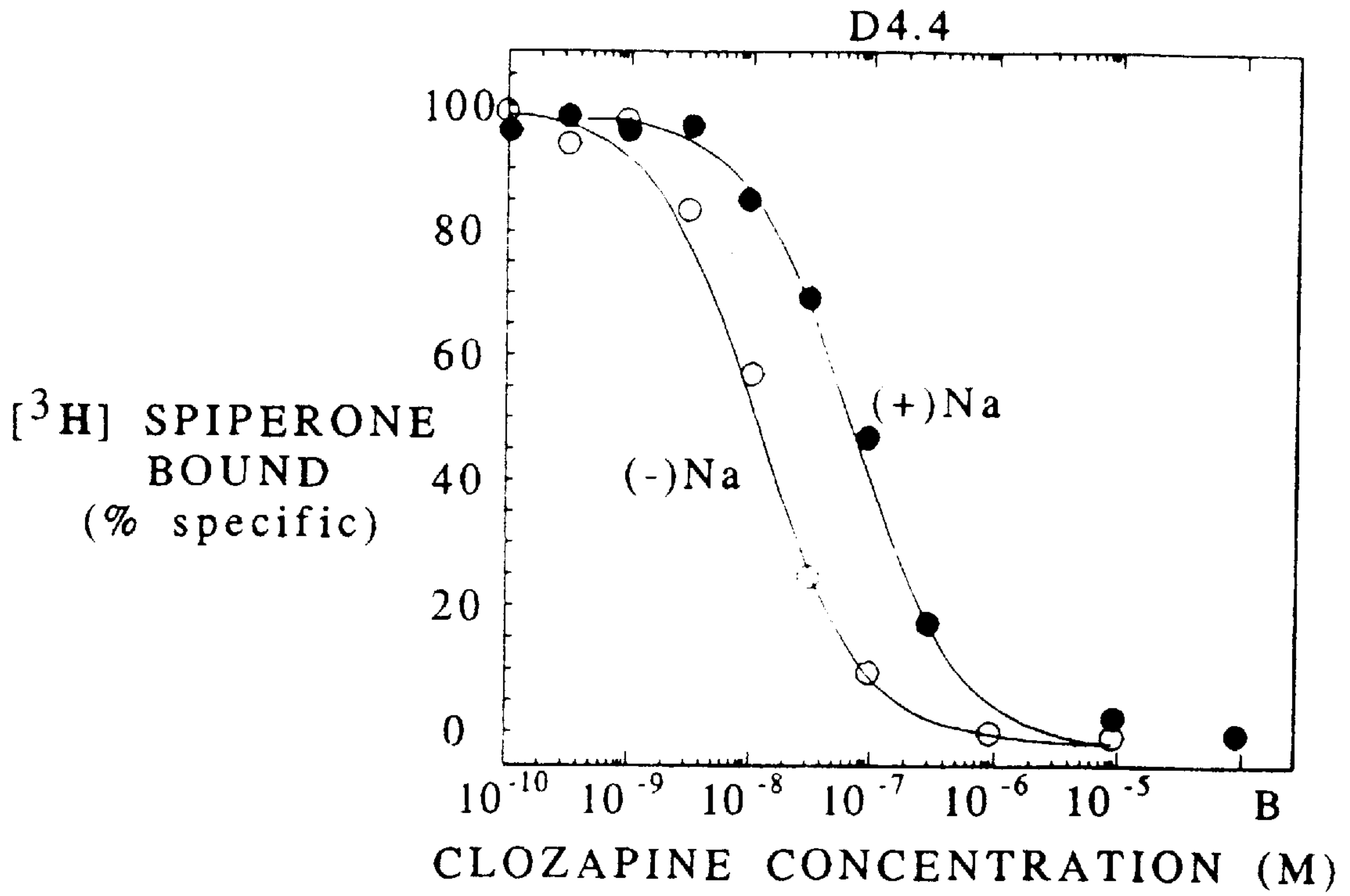


D4.2



**FIG. 9D**

**FIG. 9E**



**FIG. 9F**



**HUMAN DOPAMINE RECEPTOR AND USES**

This application is a division of Ser. No. 09/060,694 filed Apr. 16, 1998 now U.S. Pat. No. 6,203,998 which is a division of Ser. No. 08/487,811 filed Jun. 7, 1995 now U.S. Pat. No. 5,883,226 which is a division of Ser. No. 07/928,611 filed Aug. 19, 1992, now U.S. Pat. No. 5,569,601.

This application is a continuation-in-part of U.S. patent application Ser. No. 07/626,618, filed on Dec. 7, 1990, now U.S. Pat. No. 5,422,265 which is hereby incorporated by reference.

This invention was made with government support under NIMH grant MH-45614 awarded by the National Institutes of Health, United States of America, and grant PG 11121 awarded by the Medical Research Council of Canada. The governments have certain rights in the invention.

**BACKGROUND OF THE INVENTION****1. Field of the Invention**

The invention relates to dopamine receptors from mammalian species and the genes corresponding to such receptors. In particular, it relates to the human dopamine receptor D4. Specifically, the invention relates to the isolation, cloning and sequencing of the human D4 receptor gene. The invention also relates to the construction of eukaryotic expression vectors capable of expression of the human D4 dopamine receptor in cultures of transformed eukaryotic cells and the synthesis of the human D4 dopamine receptor in such cultures. The invention relates to the use of such cultures of transformed eukaryotic cells producing the human D4 dopamine receptor for the characterization of antipsychotic drugs.

**2. Information Disclosure Statement**

Dopamine is a neurotransmitter that participates in a variety of different functions mediated by the nervous system, including vision, movement, and behavior (see generally Cooper et al., 1978, *The Biochemical Basis of Neuropharmacology*, 3d ed., Oxford University Press, New York, pp. 161–195). The diverse physiological actions of dopamine are in turn mediated by its interaction with two of the basic types of G protein-coupled receptors, D1 and D2, which respectively stimulate and inhibit the enzyme adenylyl cyclase (Kebabian & Calne, 1979, *Nature* 277: 93–96). Alterations in the number or activity of these receptors may be a contributory factor in disease states such as Parkinson's disease (a movement disorder) and schizophrenia (a behavioral disorder).

A great deal of information has accumulated on the biochemistry of the D1 and D2 dopamine receptors, and methods have been developed to solubilize and purify these receptor proteins (see Senogles et al., 1986, *Biochemistry* 25: 749–753; Sengoles et al., 1988, *J. Biol. Chem.* 263: 19886–19902; Gingrich et al., 1988, *Biochemistry* 27: 3907–3912). The D1 dopamine receptor in several tissues appears to be a glycosylated membrane protein of about 72 kD (Amlaiky et al., 1987, *Mol. Pharmacol.* 31: 129–134; Ninik et al., 1988, *Biochemistry* 27: 7594–7599). The D2 receptor has been suggested to have a higher molecular weight of about 90–150 kD (Amlaiky & Caron, 1985, *J. Biol. Chem.* 260: 1983–1986; Amlaiky & Caron, 1986, *J. Neurochem.* 47: 196–204; Jarvie et al., 1988, *Mol. Pharmacol.* 34: 91–97). Much less is known about a recently discovered additional dopamine receptor, termed D3 (Sokoloff et al., 1990, *Nature* 347: 146–151).

Dopamine receptors are primary targets in the clinical treatment of psychomotor disorders such as Parkinson's

disease and affective disorders such as schizophrenia (Seeman et al., 1987, *Neuropsychopharm.* 1: 5–15; Seeman, 1987, *Synapse* 1: 152–333). The three different dopamine receptors (D1, D2, D3) have been cloned as a result of nucleotide sequence homology which exists between these receptor genes (Bunzow et al., 1988, *Nature* 336: 783–787; Grandy et al., 1989, *Proc. Natl. Acad. Sci. USA* 86: 9762–9766; Dal Toso et al., 1989, *EMBO J.* 8: 4025–4034; Zhou et al., 1990, *Nature* 346: 76–80; Sunahara et al., 1990, *Nature* 346: 80–83; Sokoloff et al., 1990, *Nature* 347: 146–151).

The antipsychotic clozapine is useful for socially withdrawn and treatment-resistant schizophrenics (see Kane et al., 1990, *Nature* 347: 146–151), but unlike other antipsychotic drugs, clozapine does not cause tardive dyskinesia (see Casey, 1980, *Psychopharmacology* 99: 547–553). Clozapine, however, has dissociation constants for D2 and D3 which are 3 to 30-fold higher than the therapeutic free concentration of clozapine in plasma water (Ackenheil et al., 1976, *Arzneim-Forsch* 26: 1156–1158; Sandoz Canada, Inc., 1990, Clozaril: Summary of preclinical and clinical data). This suggests the existence of dopamine receptors more sensitive to the antipsychotic clozapine than those known in the prior art heretofore.

We have cloned and sequenced such a human dopamine receptor which we term D4. The dopamine D4 receptor gene has high homology to the human dopamine D2 and D3 receptor genes. The pharmacological profile of this receptor resembles that of the D2 and D3 receptors but it has an affinity for clozapine which is tenfold higher. The present inventors envision that the D4 dopamine receptor disclosed as this invention may prove useful in discovering new types of drugs for schizophrenia that like clozapine do not induce tardive dyskinesia and other motor side effects.

We have also discovered that the D4 gene is polymorphic in the human population, having at least 7 different alleles that can be detected by restriction fragment length polymorphism analysis (see, Botstein et al., 1980, *Am. J. Hum. Genet.* 32: 314–331). This is the first receptor in the catecholamine receptor family which displays polymorphic variations in the human population. The observed polymorphism in dopamine D4 receptor genes may underlie individual differences in susceptibility to neuropsychiatric disorders such as schizophrenia and manic depression, as well as responsiveness to antipsychotic medication.

**DESCRIPTION OF THE DRAWINGS**

FIG. 1 illustrates the structure of a genomic clone comprising the human D4 dopamine receptor gene.

FIG. 2 illustrates the nucleotide sequence of genomic and cDNA clones of the human D4 dopamine receptor gene.

FIG. 3 provides an amino acid sequence alignment of mammalian dopamine receptors.

FIG. 4 shows the binding of [<sup>3</sup>H]spiperone to membranes of COS-7 cell transfected with a recombinant expression construct that expresses the human D4 receptor protein.

FIG. 5 demonstrates the pharmacological specificity of [<sup>3</sup>H]spiperone binding to COS-7 cells transfected with a human D4 receptor expression construct.

FIG. 6 illustrates the structure of a genomic clone comprising the human D4 dopamine receptor gene and the nucleic acid and corresponding amino acid sequences of 2, 4 and 7 copies of a novel 48 bp tandem repeat.

FIG. 7 illustrates restriction fragment length polymorphic variants of the human D4 receptor gene in 9 individuals.



FIG. 8 demonstrates the transcriptional integrity of each of three colored variant human D4 receptor gene expression constructs expressed in transfected COS-7 cells.

FIG. 9 illustrates Scatchard analysis (panels a) and [<sup>3</sup>H]-spiperone competition binding experiments (panels b) of each of three cloned variant human D4 receptor gene expression constructs expressed in transfected COS-7 cells.

### SUMMARY OF THE INVENTION

The present invention is directed toward the isolation, characterization and pharmacological use of the human D4 dopamine receptor, the gene corresponding to this receptor, a recombinant eukaryotic expression construct capable of expressing the human D4 dopamine receptor in cultures of transformed eukaryotic cells and such cultures of transformed eukaryotic cells that synthesize the human D4 dopamine receptor.

It is an object of the invention to provide a nucleotide sequence encoding a mammalian dopamine receptor. Further, it is an object of the invention to provide a nucleotide sequence that encodes a mammalian dopamine receptor with novel and distinct pharmacological properties. It is specifically an object of the invention to provide a nucleotide sequence encoding a mammalian dopamine receptor having the particular drug dissociation properties of the human dopamine receptor D4. In particular, the mammalian dopamine receptor encoded by the nucleotide sequence of the present invention has a high affinity for the drug clozapine. The human D4 dopamine receptor embodied in the present invention shows a dissociation constant (termed  $K_i$ ) of 1–40 nanomolar (nM), preferably 1–20 nM, most preferably 11 nM clozapine, as detected by the [<sup>3</sup>H]spiperone binding assay disclosed herein. The human D4 dopamine receptor embodied in the present invention displays the following pharmacological profile of inhibition of [<sup>3</sup>H]spiperone binding in the [<sup>3</sup>H]spiperone binding assay: spiperone > eticlopride > clozapine > (+)-butaclamol > raclopride > SCH23390. In a preferred embodiment of the invention, the nucleotide sequence encoding a dopamine receptor encodes the human dopamine receptor D4.

The present invention provides a nucleotide sequence encoding a mammalian dopamine receptor that is the human D4 receptor. In a preferred embodiment, this nucleotide sequence comprises a cDNA sequence isolated from RNA derived from the human neuroblastoma cell line SK-N-MC [SEQ ID No: 17], comprising the sequences of the D4.2 allele of the human D4 dopamine receptor gene. In another preferred embodiment, this nucleotide sequence comprises a cDNA sequence isolated from RNA derived from human pituitary gland tissue [SEQ ID No: 19]. In yet another preferred embodiment, this nucleotide sequence comprises a cDNA sequence isolated from RNA derived from human substantia nigra tissue [SEQ ID No.: 19]. Both of these embodiments comprise the sequences of the D4.4 allele of the human D4 dopamine receptor gene.

The invention also includes a nucleotide sequence derived from human genomic DNA [SEQ ID Nos.: 1,3,4,5,7,12,14 & 15] comprising the sequences of the D4.7 allele of the human D4 dopamine receptor gene, and a nucleotide sequence derived from human genomic DNA [SEQ ID Nos.: 1,3,4,5,7,10,14 & 15] comprising the sequences of the D4.4 allele of the human D4 dopamine receptor gene. In this embodiment of the invention, the nucleotide sequence includes 5 kilobases (kb) of human genomic DNA encoding the dopamine receptor D4. This embodiment includes the

sequences present in the cDNA embodiments as well as nucleotide sequences of 5' untranslated sequence, three intervening sequences that interrupt the coding sequence of the human D4 dopamine receptor gene, and 3' untranslated sequences. Also provided is a cDNA sequence derived from the genomic DNA sequence of the D4.4 allele [SEQ ID No: 19] and the D4.7 allele [SEQ ID No: 21] of the human D4 dopamine receptor gene.

The invention includes a nucleotide sequence of a human D4 receptor molecule, and includes allelic variations of this nucleotide sequence and the corresponding D4 receptor molecule, either naturally occurring or the product of in vitro chemical or genetic modification, having essentially the same nucleotide sequence as the nucleotide sequence of the human D4 receptor disclosed herein, wherein the resulting human D4 receptor molecule has substantially the same drug dissociation properties of the human D4 receptor molecule corresponding to the nucleotide sequence described herein. Specific preferred embodiments include alleles D4.2, D4.4 and D4.7 of the human D4 dopamine receptor gene, as defined herein.

The invention provides sequences of the naturally-occurring alleles of the human D4 dopamine receptor gene. Such alleles are defined as comprising from about 2 to about 8 repeats of a nucleotide sequence that is substantially homologous to the sequence [SEQ ID Nos: 8,10,12,17,19, 21]:

A CCC GCG CCC CGC CTC CCC CAG GAC CCC TGC  
GGC CCC GAC TGT GCG CC.

Allelic variations of this nucleotide sequence and the corresponding D4 receptor molecule, either naturally occurring or the product of in vitro chemical or genetic modification, having essentially the same nucleotide sequence as the nucleotide sequence of the human D4 receptor disclosed herein, wherein the resulting human D4 receptor molecule has substantially the same drug dissociation properties of the human D4 receptor molecule corresponding to the nucleotide sequence described herein are additional preferred embodiments of the invention. Specific preferred embodiments include the allele D4.2, comprising 2 copies of the repeat tandemly repeated [SEQ ID Nos: 8 & 17]; the allele D4.4, comprising 4 copies of the repeat tandemly repeated [SEQ ID Nos: 10 & 19]; and the allele D4.7, comprising 7 copies of the repeat tandemly repeated [SEQ ID Nos: 12 & 21].

The invention also includes a predicted amino acid sequence for the human D4 dopamine receptor deduced from the nucleotide sequence comprising the complete coding sequence of the D4 dopamine receptor gene [SEQ ID Nos: 18, 20 & 22]. Specific preferred embodiments comprise the amino acid sequence of the naturally-occurring alleles of the human D4 dopamine receptor gene. Such alleles are defined as comprising from about 2 to about 8 repeats of an amino acid sequence that is substantially homologous to the sequence [SEQ ID Nos: 9,11,13,18,20, 22]:

(P/A)AP(R/G)LP(Q/R/P)(D/G)PCG(P/S)(D/N)CAP

Allelic variations of this amino acid and the corresponding D4 receptor molecule, either naturally occurring or the product of in vitro chemical or genetic modification, having essentially the same amino acid sequence as the human D4 receptor disclosed herein, wherein the human D4 receptor molecule has substantially the same drug dissociation properties of the human D4 receptor molecule corresponding to the amino acid sequence described herein are additional preferred embodiments of the invention. Specific preferred embodiments include the allele D4.2, comprising 2 copies of



the repeat tandemly repeated [SEQ ID Nos: 9 & 18]; the allele D4.4, comprising 4 copies of the repeat tandemly repeated [SEQ ID Nos: 11 & 20]; and the allele D4.7, comprising 7 copies of the repeat tandemly repeated [SEQ ID Nos: 13 & 22].

This invention provides both nucleotide and amino acid probes derived from these sequences. The invention includes probes isolated from either cDNA or genomic DNA clones, as well as probes made synthetically with the sequence information derived therefrom. The invention specifically includes but is not limited to oligonucleotide, nick-translated, random primed, or in vitro amplified probes made using cDNA or genomic clones embodying the invention, and oligonucleotide and other synthetic probes synthesized chemically using the nucleotide sequence information of cDNA or genomic clone embodiments of the invention. The sequence information provided by the present invention is also intended to provide the basis for in vitro amplification methods for detecting D4 dopamine receptor alleles comprising the genotype of somatic and germ cells, zygotes, embryos, and tissues in humans and other mammals for diagnostic, therapeutic and other purposes.

It is a further object of this invention to provide sequences of the human D4 dopamine receptor for use as probes to determine the pattern, amount and extent of expression of this receptor in various tissues of mammals, including humans. It is also an object of the present invention to provide probes derived from the sequences of the human D4 dopamine receptor to be used for the detection and diagnosis of genetic diseases. It is an object of this invention to provide probes derived from the sequences of the human D4 dopamine receptor to be used for the detection of novel related receptor genes.

The present invention also includes synthetic peptides made using the nucleotide sequence information comprising the cDNA or genomic clone embodiments of the invention. The invention includes either naturally occurring or synthetic peptides which may be used as antigens for the production of D4 dopamine receptor-specific antibodies, or used for competitors of the D4 receptor molecule for drug binding, or to be used for the production of inhibitors (or blockers) of the binding of dopamine or dopamine analogs of the D4 dopamine receptor molecule. As used herein, the term "inhibitor of dopamine binding" is intended to encompass biochemical agonists and/or antagonists of dopamine binding to the D4 dopamine receptor.

In addition, this invention includes recombinant DNA constructs comprising the human D4 dopamine receptor and sequences that mediate the replication and selected growth of microorganisms that carry this construct.

The present invention provides recombinant expression constructs comprising the nucleotide sequence of the human D4 dopamine receptor and sequences sufficient to direct the synthesis of the human D4 dopamine receptor protein in cultures of transformed eukaryotic cells. In preferred embodiments, the recombinant expression construct is comprised of plasmid sequences derived from the plasmid pCD-PS and D4 dopamine receptor sequences corresponding to cDNA sequences for alleles D4.2, D4.4 and D4.7, as defined herein, as well as a hybrid human D4 dopamine gene, comprised of the entirety of the genomic sequences from a particular D4 dopamine genomic clone described herein, up to a PstI site located in exon III, followed by the remainder of the coding and 3' untranslated sequences found in a particular human cDNA sequence derived from a human neuroblastoma cell line. Recombinant expression constructs

of the invention also encompass embodiments comprising allelic variations of the human D4 dopamine receptor genomic DNA sequences and cDNA-derived sequences. This invention includes recombinant expression constructs comprising essentially the nucleotide sequences of genomic and cDNA clones of the human D4 dopamine receptor and allelic variations thereof in embodiments that provide for the expression of human D4 dopamine receptor protein in cultures of transformed eukaryotic cells.

It is also an object of this invention to provide cultures of transformed eukaryotic cells that have been transformed with such recombinant expression constructs and that synthesize human D4 dopamine receptor protein. In a preferred embodiment, the invention provides monkey COS cells that synthesize human D4 dopamine receptor protein.

The present invention also includes protein preparations of the human D4 dopamine receptor, and preparations of membranes containing the human D4 dopamine receptor, derived from cultures of eukaryotic cells transformed with the recombinant expression constructs of the invention. In a preferred embodiment, cell membranes containing human D4 dopamine receptor protein are isolated from culture of COS-7 cells transformed with a recombinant expression construct that directs the synthesis of human D4 dopamine receptor.

It also an object of this invention to provide the human D4 dopamine receptor for use in the in vitro screening of novel antipsychotic compounds. In a preferred embodiment, membrane preparations containing the human D4 dopamine receptor, derived from cultures of eukaryotic cells transformed with the recombinant expression constructs of the invention, are used to determine the drug dissociation properties of antipsychotic compounds in vitro. These properties are then used to characterize novel antipsychotic compounds by comparison to the binding properties of known antipsychotic compounds.

The present invention will also be useful for the detection of dopamine and dopamine analogues, known or unknown, either naturally occurring or as the embodiments of antipsychotic or other drugs.

It is an object of the present invention to provide a method for the quantitative detection of dopamine and dopamine analogues, either naturally occurring or as the embodiments of antipsychotic or other drugs. It is an additional object of the invention to provide a method to detect dopamine or dopamine analogues in blood, saliva, semen, cerebrospinal fluid, plasma, lymph, or any other bodily fluid.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The term "D4 dopamine receptor" as used herein refers to proteins substantially homologous to, and having substantially the same biological activity as, the protein coded for by the nucleotide sequences depicted in FIG. 2 and FIG. 6 (i.e., proteins which display high affinity binding to clozapine) [SEQ ID Nos: 1,3,4,5,7,8,10,12,14 & 15]. This definition is intended to encompass natural allelic variations in the D4 dopamine receptor sequence, specifically including the alleles D4.2, D4.4 and D4.7, as defined herein [SEQ ID Nos.: 17,19 & 21], and all references to the D4 dopamine receptor, and nucleotide and amino acid sequences thereof are intended to encompass such allelic variations, both naturally-occurring and man-made. Clone genes of the present invention may code for D4 dopamine receptors of any species of origin, including, mouse, rat, rabbit, cat, and human, but preferably code for receptors of mammalian, most preferably human, origin.



The production of proteins such as the D4 dopamine receptor from cloned genes by genetic engineering is well known (see, e.g., U.S. Pat. No. 4,761,371 to Bell et al. at Col. 6 line 3 to Col. 9 line 65; the disclosure of all U.S. patent references cited herein is to be incorporated herein by reference). The discussion which follows is accordingly intended as an overview of this field, and is not intended to reflect the full state of the art.

DNA which encodes the D4 dopamine receptor may be obtained, in view of the instant disclosure, by chemical synthesis, by screening reverse transcripts of mRNA from appropriate tissues, cells or cell line cultures, by screening genomic libraries from appropriate cells, or by combinations of these procedures, as illustrated below. Screening of mRNA or genomic DNA may be carried out with oligonucleotide probes generated from the D4 dopamine receptor gene sequence information provided herein. Probes may be labeled with a detectable group such as a fluorescent group, a radioactive atom or a chemiluminescent group in accordance with known procedures and used in conventional hybridization assays, as described in greater detail in the Examples below. In the alternative, D4 dopamine receptor gene sequences may be obtained by use of the polymerase chain reaction (PCR) procedure, with the PCR oligonucleotide primers being produced from the D4-dopamine receptor gene sequence provided herein (see U.S. Pat. Nos. 4,683,195 to Mullis et al. and 4,683,202 to Mullis).

The D4 dopamine receptor may be synthesized in host cells transformed with constructs containing DNA encoding the D4 dopamine receptor. Such constructs are replicable and are used herein either to amplify DNA encoding the D4 dopamine receptor and/or to express DNA which encodes the D4 dopamine receptor. An expression construct is a replicable DNA construct in which a DNA sequence encoding the D4 receptor is operably linked to suitable control sequences capable of effecting the expression of the D4 receptor in a suitable host. The need for such control sequences will vary depending upon the host selected and the transfection method chosen. Generally, control sequences include a transcriptional promoter, an optional operator sequence to control transcription, a sequence encoding suitable mRNA ribosomal binding sites, and sequences which control the termination of transcription and translation. When used for DNA amplification such constructs do not require expression control domains. All that is needed is the ability to replicate in a host, usually conferred to by an origin of replication, and a selective marker gene to facilitate recognition of transformants.

Constructs useful for practicing the present invention include plasmids, viruses (including phage), retroviruses, and integratable DNA fragments (i.e., fragments integratable into the host genome by homologous recombination). The construct may replicate and function independently of the host genome, or may, in some instances, integrate into the host genome itself. Suitable constructs will contain replicon and control sequences which are derived from species compatible with the intended expression host. Transformed host cells are cells which have been transformed, transfected or infected with the D4 receptor-containing constructs assembled using recombinant DNA techniques. Transformed host cells ordinarily express the D4 receptor, but host cells transformed for purposes of cloning or amplifying the D4 receptor DNA need not express the D4 receptor. When expressed, the D4 receptor will typically be located in the host cell membrane.

DNA registers are operably linked when they are functionally related to each other. For example: a promoter is

operably linked to a coding sequence if it controls the transcription of the sequence; a ribosome binding site is operably linked to a coding sequence if it is positioned so as to permit translation. Generally, operably linked means contiguous and, in the case of leader sequences, contiguous and in the same translational reading frame.

Cultures of cells derived from multicellular organisms are a desirable host for recombinant D4 dopamine receptor synthesis. In principal, any higher eukaryotic cell culture can be used, whether from vertebrae or invertebrate culture. However, mammalian cells are preferred, as illustrated in the Examples. Propagation of such cells in cell culture has become a routine procedure (see *Tissue Culture*, Academic Press: New York (Kruse & Patterson, eds.) 1973). Examples of useful host cell lines are VERO and HeLA cells, Chinese hamster ovary (CHO) cell lines, and WI138, BHK, COS-7, CV, and MDCK cell lines. Expression constructs for such cells ordinarily include (if necessary) an origin of replication, a promoter located upstream from the gene to be expressed, along with a ribosome binding site, RNA splice site (if intron-containing genomic DNA is used), a polyadenylation site, and a transcriptional termination sequence.

The transcriptional and translational control sequences in expression constructs to be used in transforming vertebrae cells are often provided by viral sources. For example, commonly used promoters are derived from polyoma, Adenovirus 2, and Simian Virus 40 (SV40; see, e.g., U.S. Pat. No. 4,599,308). The early and late promoters of SV40 are useful because both are obtained easily from the virus within a fragment which also contains the SV40 viral origin of replication (see Fiers et al., 1978, *Nature* 273: 113). Further, the human genomic D4 receptor promoter, control and/or signal sequences, may also be used, provided such control sequences are compatible with the host cell chosen.

An origin of replication may be provided either within the construct itself, such as may be derived from SV40 or other viral source (e.g., Polyoma, Adenovirus, VSV, or MPV), or may be provided by the host cell chromosomal replication mechanism. If the construct is integrated into the host cell chromosome, the latter may be sufficient.

D4 dopamine receptors made from cloned genes in accordance with the present invention may be used for screening compounds for D4 dopamine receptor activity, or for determining the amount of a dopaminergic drug in a solution (e.g., blood plasma or serum). For example, host cells may be transformed with a construct of the present invention, D4 dopamine receptors expressed in that host, the cells lysed, and the membranes from those cells used to screen compounds for D4 dopamine receptor binding activity. Competitive binding assays in which such procedures may be carried out are well known, as illustrated by the Examples below. By selection of host cells which do not ordinarily express a dopamine receptor, pure preparations of membranes containing D4 receptors can be obtained. Further, D4 dopamine receptor agonist and antagonists can be identified by transforming host cells with constructs of the present invention. Membranes obtained from such cells can be used in binding studies wherein the drug dissociation constants are measured. Such cells must contain D4 protein in the plasma and other cell membranes. Procedures for carrying out assays such as these are also described in greater detail in Examples which follow.

Cloned genes and constructs of the present invention are useful to transform cells which do not ordinarily express the D4 dopamine receptor to thereafter express this receptor. Such cells are useful as intermediates for making cell



membrane preparations for receptor binding assays, which are in turn useful for drug screening. Further, genes and constructs of the present invention are useful in gene therapy. For such purposes, retroviral constructs as described in U.S. Pat. No. 4,650,764 to Temin and Watanabe or U.S. Pat. No. 4,861,719 to Miller may be employed. Cloned genes of the present invention, or fragments thereof, may also be used in gene therapy carried out homologous recombination or site-directed mutagenesis (See generally Thomas & Capecchi, 1987, *Cell* 51: 503-512; Bertling, 1987, *Bioscience Reports* 7: 107112; Smithies et al., 1985, *Nature*, 317: 230-234).

Cloned genes of the present invention, and oligonucleotides derived therefrom, are useful for screening for restriction fragment length polymorphism (RFLP) associated with genetic polymorphisms within a population. Such RFLPs may also be associated with certain genetic disorders, and the probes provided by the invention can be used for their identification and the identification of individuals susceptible to neuropsychiatric disorders such as schizophrenia and manic depression. Such RFLPs may also be useful for predicting individual responsiveness to psychotropic and antipsychotic drugs.

Oligonucleotides of the present invention are useful as diagnostic tools for probing D4 receptor gene expression in nervous tissue. For example, tissue can be probed in situ with oligonucleotide probes carrying detectable label groups by conventional autoradiography techniques, as explained in greater detail in the Examples below, to investigate native expression of this receptor or pathological conditions relating thereto. Further, chromosomes can be probed to investigate the location of the D4 dopamine receptor gene, and potential pathological conditions related thereto, as also illustrated by the Examples below.

Oligonucleotides of the present invention are also useful for in vitro amplification of D4 dopamine receptor sequences. Amplification methods include but are not intended to be limited to the polymerase chain reaction and the ligase chain reaction. Amplification of D4 dopamine receptor sequences is useful as a diagnostic tools for analyzing and quantitating D4 receptor gene expression in tissue, for example nervous tissue. Additionally, the use of oligonucleotides synthesized or isolated according to methods well known in the art that comprise D4 dopamine receptor sequences provided by the invention permit in vitro amplification methods to be used for the detection of D4 dopamine receptor alleles comprising the genotype of somatic and germ cells, zygotes, embryos, and tissues in human and other mammals for diagnostic, therapeutic and other purposes.

The Examples which follow are illustrative of specific embodiments of the invention, and various uses thereof. They are set forth for explanatory purposes only, and are not to be taken as limiting the invention.

#### EXAMPLE 1

##### Screening Tissue and Cell Line RNA for Dopamine Receptor Expression

RNA was prepared from different rat tissues or cell lines using the guanidium thiocyanate/CsCl procedure described in Bunzow et al., 1988, *Nature* 336: 783-787. Tissues tested included heart, epididymis, testis, gut, pancreas, spleen, thymus, muscle, ventricle, atria, lung, adrenal, kidney, liver, pineal gland and pituitary. Cell lines screened included SK-N-MC, SK-N-SH, COS, AKR1, Ltk<sup>-</sup>, GH4C1, NG108-

15, AtT20, 3T3, BSC40, C6, CV-1, HeLa, IMR-32, N4TG1, NCB-20, PC-12, Rin m5f and WERI-Rb-1. 20  $\mu$ g of RNA was analyzed by Northern blot hybridization with a radio-labeled BstYI-BglIII DNA fragment of the rat D2 receptor, which encodes the putative transmembrane domains VI and VII. Blots were hybridized under standard conditions as described in Bunzow et al., *ibid.*, hybridization was performed overnight at 37° C. Blots were then washed at 55° C. in 2X standard saline-citrate (SSC) and 1% sodium dodecyl sulfate (SDS). Washed blots were exposed to X-ray film for two days at -70° C. using an intensifying screen. For comparison, the same blot was hybridized under high stringency conditions (the modifications of which include using 50% formamide and 42° C. for the hybridization and 0.2X SSC for the wash). Under conditions of low stringency the SK-N-MC cell line showed a positive signal in these experiments.

#### EXAMPLE 2

##### Construction of a cDNA Phage Library using Neuroblastoma RNA

Double-stranded cDNA was synthesized using standard techniques [see Sambrook et al., 1989, *Molecular Cloning: A Laboratory Manual*, 2d ed., Cold Spring Harbor Laboratory Press: New York] from poly(A)<sup>+</sup> mRNA isolated from the human neuroblastoma cell line SK-N-MC as described in Example 1. The cDNA was directionally cloned into the EcoRI and XhoI restriction endonuclease sites of the phage cloning vector lambda ZAPII (Stratagene, La Jolla, Calif.). The library was transferred to colony plaque screen filters (New England Nuclear, Boston, Mass.). Approximately 500,000 independent clones were screened under low-stringency hybridization conditions as described in Example 1. Hybridization was performed for 30 hrs with <sup>32</sup>P-labeled 1.6 kb BamHI-BglIII and 300 bp BstYI-BglIII fragments of a rat D2 receptor clone at a specific activity of 10<sup>6</sup> dpm/ $\mu$ g. Filters were washed at 55° C. in 2X SSC and 1% SDS. The clone D2102S was isolated and sequenced using the Sanger dideoxy chain termination method catalyzed by Sequenase (U.S. Biochemical Corporation, Cleveland, Ohio). The sequence of this clone is shown in FIG. 2 (hatched area).

The putative coding sequence is shown in capitals (non-coding sequence is in italics) and the deduced amino acid sequence is shown above the nucleotide sequence. Numbering of the putative coding sequence begins with the first methionine of the open reading frame. The sequence corresponding to the cDNA clone is hatched. Single-letter abbreviations for amino acids and nucleotides used herein can be found in G. Zubay, *Biochemistry* (2d. ed.), 1988 (MacMillan Publishing: New York) p.33. Noteworthy is the presence of a duplicated 48 bp sequence in the putative third exon, corresponding to the third cytoplasmic loop region of the D4 receptor protein. The complete nucleotide sequence of this clone has been determined (see FIG. 6, wherein these repeated sequences of this clone are designated D4.2 [SEQ ID No: 17]).

#### EXAMPLE 3

##### Screening a Genomic DNA Phage Library with a Human Dopamine Receptor Probe

Clone D210S was <sup>32</sup>P-labeled by random primed synthesis and used to screen a commercially available human genomic library cloned in the phage vector EMBL3 (Clontech, Palo Alto, Calif.). Hybridization was performed



as described in Example 2 using 50% formamide. After hybridization the filters were washed at 65° C. in 0.1X SSC and 0.1% SDS. The clone D210G was isolated and analyzed by restriction endonuclease and Southern blot analysis. The map of this genomic clone is shown in FIG. 1, wherein the structure of the D4 receptor gene is compared with the structure of the D2 gene. Relevant restriction endonuclease sites in the D4 receptor sequence are indicated. The Sall site is part of the cloning site in EMBL3. The proposed coding regions are boxed and numbered in Roman numerals. Perfect matches of proposed intron/exon junction sites are indicated by connecting stippled bars between the receptor clones.

PstI-PstI fragments of approximately 1.3 kb and 2.6 kb, and an overlapping Sall-EcoRI fragment of approximately 2.0 kb derived from the D4 receptor gene were subcloned into the plasmid pBluescript-SK (Stratagene). The subcloned fragments were characterized by sequence analysis as described above. This sequence is shown in FIG. 2. The complete nucleotide sequence of this clone has been determined (see FIG. 6, wherein these repeated sequences of this clone are designated D4.7 [SEQ ID No: 21]).

#### EXAMPLE 4

##### DNA Sequence Analysis of the Human D4 Dopamine Receptor

One of the cDNA clones detected by screening the SK-N-MC neuroblastoma library with a rat D2 probe at low stringency (D210S) contained a 780 bp EcoRI-XhoI insert which hybridized to the rat probe. Screening of a human genomic EMBL3 library (Clontech) under high stringency conditions with the clone D210S resulted in the isolation of the genomic clone D210G.

Southern blot and sequence analysis indicated that the clone contained a 5 kb Sall-PstI fragment which coded for the entire gene of D210S [SEQ ID No.: 21]. Sequence analysis of this insert showed the presence of an open reading frame with homology to the amino acid sequence of transmembrane domains V (45%), VI (46%) and VII (78%) of the D2 receptor, shown in FIG. 3. The putative amino acid sequence of the human D4 receptor [SEQ ID No.: 22] is aligned with the human and rat D2, rat D3 and human and rat D1 receptor sequences. Amino acids conserved within the group of dopamine receptors are shaded. The putative transmembrane domains are overlined and labeled by Roman numerals.

There is a potential translation initiation codon (ATG) 590 bp downstream from the Sall site, followed by an open reading frame that showed that amino acid sequence homology with transmembrane domain I (36%) and II (63%) of the D2 receptor. Almost immediately downstream from the transmembrane domain II sequence, homology to the D2 receptor disappears, indicating the presence of an intron in the genomic DNA. This intron spanned approximately 2 kb, after which sequence homology to the D2 receptor was re-established. Translation of the putative gene product showed homology to the transmembrane domains III (68%), IV (37%), V(46%) and VII (78%) of the D2 receptor (see FIG. 3).

Potential splice junction donor and acceptor sites (Mount, 1982, Nucl. Acids Res. 10: 461-472) were found in the transmembrane domains II, III and VI, as shown in FIG. 1. These splice sites were at an identical position as in the D2 and D3 receptor gene [see Grandy et al., 1989, Proc. Nat. Acad. Sci. USA 86: 9762-9766; Dal Toso et al., 1989,

EMBO J. 8: 4025-4034; Sokoloff et al., 1990, Nature 347: 146-151] and FIG. 1. The coding sequence downstream from transmembrane domain IV is identical to the sequence of clone D210S but is interrupted by an intron of about 300 bp between transmembrane domains V and VI and an additional intron of 92 bp transmembrane VI (FIG. 1, hatched area). The precise location of the splice site for the intron between transmembrane V and VI cannot be determined due to the fact that a sequence of 52 bp present in the coding sequence is repeated exactly on either side of the intron (FIG. 2).

The deduced amino acid sequence from the genomic and cDNA nucleotide sequences indicated that this gene codes for a protein of 387 amino acids with an apparent molecular weight of 41 kD. A hydrophobicity plot of the protein sequence suggests the existence of seven transmembrane domains. These regions correlative with the observed homologous regions in the human D2 receptor and other receptors belonging to the family of G-protein coupled receptors (Dohlman et al., 1987, Biochemistry 26:2657-2664; Bunzow et al., 1988, Nature 336: 783-787; Sokoloff et al., 1990, Nature 347: 146-151; and FIG. 2). A potential N-linked glycosylation site (Hubbard & Ivatt, 1981, Ann. Rev. Biochem. 50: 555-583) is located two amino acids downstream from the initiation methionine. The amino acid residues Asp (80) and Asp (115) in the D4 receptor, which are conserved within the family catecholaminergic receptors, are postulated to act as "counterions" in catecholamine binding (Strader, et al., 1988, J. Biol. Chem. 263: 10267-10271). Also conserved within the family of catecholaminergic receptors are Ser (197) and Ser (700) which have been suggested to interact with the catechol hydroxyl groups (Kozak, 1984, Nucleic Acids Res. 12: 857-872). Several consensus sites for potential phosphorylation by protein kinase C and protein kinase A are found in the third cytoplasmic loop (Sibley et al., 1987, Cell 48: 913-922; Bouvier et al., 1988, Nature 333: 370-373). The Cys (187), which may serve as a substrate for palmitoylation, is conserved in most of the G-protein coupled receptors (O'Dowd et al., 1989, J. Biol. Chem 264: 7564-7569). The short carboxyl tail, which terminates similar to the D2 and D3 receptor at Cys (387) (Bunzow et al., 1988, Nature 336: 783-787; Grandy et al., 1989, Proc. Natl. Acad. Sci. USA 86: 9762-9766; Dal Toso et al., 1989, EMBO J. 8: 4025-4034; Sokoloff et al., 1990, Nature 347: 146-151), and the relatively large third cytoplasmic loop, are features observed in most receptors which interact with an isoform of the G protein.

A noteworthy feature of the sequence of the third exon of the genomic D4 receptor clone is the presence of a 7-fold repeat of a GC rich, 48 bp sequence, beginning at nucleotide 447 of exon III, and encodes a proline-rich portion of the D4 dopamine receptor protein (see FIG. 6, wherein the sequences of this clone are designated D4.7 [SEQ ID No.:21]). This region of the protein corresponds to the putative third cytoplasmic loop of the receptor protein molecule [SEQ ID No.: 22]. This sequence corresponds to the 2-fold repeat of a homologous sequence found in the SK-N-MC neuroblastoma cDNA sequence described in Example 2, suggesting that the D4 receptor gene may be polymorphic. This sequence is uniquely found in the D4 receptor and is not homologous to any other known dopamine receptor protein. Interestingly, this region of the human D4 receptor is not found in the rat homologue of the D4 receptor, making this variation specific to humans.

From these results we have concluded that the sequences we have isolated encode a polymorphic member of the dopamine receptor family.



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## EXAMPLE 5

## Construction of an Mammalian DNA Expression Construct using Dopamine Receptor cDNA

The ApaI-PstI gene fragment (FIG. 1, the PstI site found in exon III after transmembrane domain V) was ligated to the corresponding PstI-EcoRI cDNA fragment isolated from the SK-N-MC cDNA. This construct was then cloned into the vector pCD-PS (Bonner et al., 1989, Neuron 1: 403-410). This vector allows for the expansion of the human D4 receptor gene from the SV40 promoter. Large quantities of the pCD-PS-D4 construct plasmid were prepared using standard techniques (see, Sambrook, et al., *ibid.*). This plasmid was transfected into COS-7 cells by the calcium phosphate precipitation technique (Gorman et al., 1983, Science 221: 551-553). Two days later membranes cells were harvested and analyzed as described in Example 6.

## EXAMPLE 6

## Analysis of Dopamine and Dopamine-Antagonist Binding of D4 Dopamine Receptor

Cells were harvested and homogenized using a teflon pestle in 50 mM Tris-HCl (pH 7.4 at 4° C.) buffer containing 5 mM EDTA, 1.5 mM CaCl<sub>2</sub>, 5 mM MgCl<sub>2</sub>, 5 mM KCl and 120 nM NaCl. Homogenates were centrifuged for 15 minutes at 39,000 g, and the resulting pellets resuspended in buffer at a concentration of 150-250 µg/ml. For saturation experiments, 0.25 ml aliquots of each tissue homogenate was incubated in duplicate with increasing concentrations of [<sup>3</sup>H]spiperone (70.3 Ci/mmol; 10-3000 pM final concentration) for 120 min at 22° C. in a total volume of 1 ml. The results of these experiments are shown in FIG. 4. The results shown are representative of two independent experiments each conducted in duplicate (the inset show a Scatcherd plot of the same data). Estimated B<sub>max</sub> (approximately 260 fmol/mg protein) and K<sub>i</sub> (70 pM) values were obtained by LIGAND computer program.

Representative curves are shown in FIG. 5 for the concentration dependent inhibition of [<sup>3</sup>H]spiperone binding by various dopaminergic agonist and antagonists. Estimated K<sub>i</sub> values are listed in Table I along with the K<sub>i</sub> values obtained on the human D2 receptor expressed in GH(4)ZR(7) cells. For competition binding experiments, assays were initiated by the addition of 0.25 ml of membrane preparation and incubated in duplicate with the concentrations of competing ligands indicated in FIG. 5 (10<sup>-14</sup> to 10<sup>-3</sup> M) and [<sup>3</sup>H]spiperone (150-300 pM) for 120 min at 22° C. Assays were terminated by rapid filtration through a Titertek cell harvester and filters subsequently monitored to quantitate radioactive tritium. For all experiments, specific [<sup>3</sup>H]spiperone binding was defined as that binding inhibited by 10 µM (+)sulpiride. Both saturation and competition binding data were analyzed by the non-linear least square curve-fitting program LIGAND run on a Digital Micro-PDP-11. The human D4 dopamine receptor displays the following pharmacological profile of inhibition of [<sup>3</sup>H]spiperone binding in this assay: spiperone>eticlopride>clozapine>(+)butaclamol>raclopride>SCH23390.

## EXAMPLE 7

## Polymorphic Allelic Variants of the D4 Dopamine Receptor Isolated from Human Tissue cDNA Libraries

Human cDNA libraries were screened for expression of polymorphic variants of the human D4 receptor gene. A

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human substantia nigra cDNA library constructed in lambda gt11 (Clontech) and a pituitary cDNA library constructed in lambda gt10 as described in Example 2 were screened for clones encoding the D4 receptor. Approximately 0.1-1×10<sup>6</sup> plaque-forming units (p.f.u.) were transferred in duplicate to nylon filters (DuPont/NEN) and probed with a <sup>32</sup>P-labeled 700 bp EcoRI-XhoI fragment encoding the cDNA isolated from the neuroepithelioma SK-N-MC under conditions as described in Example 2 above.

Screening of cDNA libraries from human pituitary and substantia nigra resulted in the isolation of variant cDNA clones of the D4 receptor. The pituitary lambda gt10 clone contained a 1.4-kb EcoRI insert, coding for intron 1 and the down-stream sequences of the D4 receptor. This pituitary D4 receptor clone also contained the second intron, but the last intron was spliced out. The isolated substantia nigra lambda gt11 clone contained a 600-bp EcoRI insert, coding for the D4 receptor, starting in the 5' site of the putative third cytoplasmic loop. Both these clones contained a four-fold repeat (see FIG. 6, wherein these sequences of these clones are designated D4.4 [SEQ ID No.: 19]) of the 48-bp sequence previously found as a 7-fold repeat in the D4 genomic clone D210G (Example 4) and a 2-fold repeat in the neuroblastoma SK-N-MC cDNA clone (Example 2) within the putative third cytoplasmic loop of the D4 receptor protein (compare, SEQ ID Nos.: 18, 20 & 22]. A comparison of the nucleic acid sequences revealed that, due to the absence of conventional splice junction sites in the seven-fold repeat sequence of the genomic clone, a novel splicing mechanism would be required to account for the existence of the different cDNA clones.

Two different human genomic libraries from different human individuals (Clontech) were screened to detect allelic polymorphism in the human D4 receptor gene. Screening of genomic libraries resulted in the isolation of a genomic clone with a 4-fold repeat of the 48 bp sequence previously detected in pituitary and substantia nigra cDNA. This result indicated that the polymorphic cDNA molecules resulted from genetic polymorphic variation in the corresponding genomic DNA, due to the existence of polymorphic alleles in the human population for the D4 receptor.

## EXAMPLE 8

## Additional D4 Receptor Gene Allelic Variants Found by RFLP Analysis of Human Genomic DNA

The three different D4 receptor sequences predict a restriction fragment length polymorphism for a HincII-PstI fragment of the D4 gene (FIG. 6). Southern blot analysis of human genomic DNA was performed as described (see Sambrook et al., *ibid.* and Example 3). A RFLP was observed in humans and the different allelic fragments were sized.

Briefly, high molecular weigh genomic DNA was isolated from human blood samples using proteinase K and phenol/chloroform extractions. Genomic DNA (5 µg) was digested with the restriction endonucleases HincII and PstI and size separated by agarose (1%) gel electrophoresis. DNA was transferred to nylon membranes (Zeta-probe, Biorad) according to standard techniques (Sambrook et al., *ibid.*). Southern blots were probed with a <sup>32</sup>P-labeled 600 bp EcoRI-HincII fragment, coding for the D4 cDNA isolated from the neuroepithelioma SK-N-MC, and washed at high stringency (65° C., 0.1×SSC, 0.1% SDS, 40 min). The blot was exposed to X-ray film for three days. Results of these experiments are shown in FIG. 7.



The position of a 504-bp size marker is indicated on the left. D4-hybridizing polymorphic bands can be seen at approximately 520 bp, 620 bp, 710 bp, 760 bp and 800 bp. [It will be recognized to those with skill in this art that the sizes given herein for the alleles of the human D4 dopamine receptor gene are limited in their precision to the resolving power of the agarose gels used in the analyses. The sizes are approximate as given herein, and more exact sizes can be calculated from the sequences of the different alleles found in SEQ ID Nos: 17, 19 & 21.] The 520 bp, 620 bp and 760 bp fragments correlate closely with the sizes of the HincII-PstI fragments of the cloned D4 receptor variants with the two-, four- and seven-fold repeat sequences respectively. The presence of 710 bp and 800 bp fragments suggests that variant with six-fold and eight-fold repeat sequences also exist. Additional population screening experiments have resulted in the detection of alleles corresponding to three-fold and five-fold repeats. A total of 7 alleles of the D4 receptor gene have accordingly been found in the human population.

#### EXAMPLE 9

##### Expression of Allelic Variants of the D4 Receptor

Mammalian DNA expression constructs were made as described in Example 5 for expression of the allelic variants of the D4 receptor. Various cDNA constructs were cloned into the expression vector pCD-PS (see Example 5) which contains the SV40 origin of replication and drives expression of the cloned inserts from the SV40 late promoter. A 1.7-kb KpnI-XbaI fragment comprising a cDNA for the D4 receptor gene containing the 7-fold repeat was cloned into the pCD-PS vector of Example 5 and called hereafter pCD-D4.7. Full-length cDNA clones for the D4.2 and D4.4 forms of the receptor were made by in vitro recombination between partial cDNA clones of these forms with the full-length cDNA clone of the D4.7 receptor variant. The clone pCD-D4.4 was created by substituting the 920-bp PstI-EcoRI 3' fragment of pCD-D4.7 with the 730-bp PstI-EcoRI fragment of the D4 cDNA isolated from human pituitary. In a similar fashion the clone pCD-D4.2 was constructed by exchange of this 3' PstI-EcoRI fragment of pCD-D4.7 with a 630-bp PstI-EcoRI fragment of the D4.2 cDNA clone isolated from the neuroepithelioma SK-N-MC.

Transient expression in COS-7 cells was achieved as follows. Cells harvested and washed in phosphate buffered saline (PBS).  $5 \times 10^7$  cells were resuspended in 1 ml PBS with 100  $\mu\text{g}/\text{ml}$  plasmid DNA (purified by caesium chloride gradient centrifugation) and incubated for 10 min on ice. Next, 400  $\mu\text{l}$  aliquots of the cell suspension were subjected to an electric field of 0.65 kV/cm, 4.1 ms pulse duration using a BTX 600 Electro Cell Manipulator (Biotechnologies & Experimental Research, Inc., San Diego, Calif.). After the electric pulse, the cells were incubated for another 10 min on ice and then seeded in Modified Eagle's Medium supplemented with 10% fetal calf serum. The next day the medium was renewed. Three days after electroporation the cells were harvested and stored at  $-80^\circ\text{C}$ . until use in receptor binding studies as described herein

Expression of each of the cloned variant D4 receptor constructs was demonstrated by Northern blot analysis as described in Example 1. Blots were hybridized with the 700 bp EcoRI-XhoI fragment of the D4 cDNA isolated from the neuroepithelioma SK-N-MC (Example 2). The results of these experiments are shown in FIG. 8. Transient expression of the three forms in COS-7 cells as characterized in these experiments demonstrated the expected size and size differ-

ences between the three forms, indicating that none of the expressed D4 receptor RNAs are further processed or produced from one another by RNA splicing events. Furthermore, the two bands observed for the D4.2 and D4.4 clones represent the consequence of the use of either the endogenous D4 receptor polyadenylation signal or the SV40 (vector-derived) polyadenylation signal). These observations indicate that in the transient expression system the expression of the three different clones would result in the formation of three structurally different receptors.

#### EXAMPLE 10

##### Analysis of Dopamine and Dopamine-Antagonist Binding of Variant D4 Dopamine Receptors

Pharmacological analysis of dopamine agonist and antagonist binding was performed as described in Example 6. The results of these experiments are shown in FIG. 9. Panels (a) illustrate Scatchard analysis of the saturation isotherms for [ $^3\text{H}$ ]spiperone binding to membranes prepared from COS-7 cells transiently transfected with pCD-D4.2 (D4.2), pCD-D4.4 (D4.4) and pCD-D4.7 (D4.7). Panels (b) show clozapine competition of [ $^3\text{H}$ ]spiperone binding for the three allelic forms of the D4 receptor in the presence (+Na<sup>+</sup>) and absence (-Na<sup>+</sup>) of sodium chloride.

Pharmacological analysis demonstrated that all three variants displayed saturable [ $^3\text{H}$ ]spiperone binding (300–1000 fmol  $\text{mg}^{-1}$ ) with similar dissociation constants in the absence of sodium chloride ( $K_d=40\text{--}50$  pM; FIG. 4a). However, in the presence of 120 mM sodium chloride, the dissociation constants increased approximately two- to three-fold for D4.2 and D4.4 but not for D4.7.

Clozapine competition of [ $^3\text{H}$ ]spiperone binding revealed that D4.2 and D4.4 had lower dissociation constants for clozapine in the absence of sodium chloride ( $K_i=3$  nM without sodium chloride;  $K_i=23$  nM with sodium chloride). D4.7 had a dissociation constant of approximately 15 nM for clozapine which did not exhibit sodium chloride sensitivity ( $K_i=12$  nM without sodium chloride;  $K_i=18$  nM with sodium chloride; shown in FIG. 4b). This sodium chloride-mediated effect for clozapine on the D4 variants was not modulated by guanine nucleotides.

Agonists and antagonists (dopamine, bromocriptine, raclopride and clozapine) inhibited [ $^3\text{H}$ ]spiperone binding (in the presence of sodium chloride) to these different D4 receptor variants in a concentration-dependent manner with similar dissociation constants. Furthermore, all three variants exhibited a guanine nucleotide-sensitive high-affinity form of the receptor upon competition with dopamine, suggesting that all these variants can functionally couple to G-proteins. Thus, we have defined a novel, polymorphic dopamine receptor which we term D4.

It should be understood that the foregoing disclosure emphasizes certain specific embodiments of the invention and that all modifications or alternatives equivalent thereto are within the spirit and scope of the invention as set forth in the appended claims.

## SEQUENCE LISTING

## (1) GENERAL INFORMATION:

(iii) NUMBER OF SEQUENCES: 22

## (2) INFORMATION FOR SEQ ID NO: 1:

## (i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 388 base pairs  
(B) TYPE: nucleic acid  
(C) STRANDEDNESS: single  
(D) TOPOLOGY: linear

## (ii) MOLECULE TYPE: DNA (genomic)

(B) CLONE: Cloning of the gene for a human dopamine D4 receptor with high affinity for the antipsychotic clozapine

## (ix) FEATURE:

(A) NAME/KEY: 5'UTR  
(B) LOCATION: 1..103

## (ix) FEATURE:

(A) NAME/KEY: exon  
(B) LOCATION: 104..388

## (ix) FEATURE:

(A) NAME/KEY: CDS  
(B) LOCATION: 104..388

## (x) PUBLICATION INFORMATION:

(A) AUTHORS: Van Tol, Hubert H.M.

Wu, Caren M.  
Guan, Hong-Chang  
Ohara, Koichi  
Bunzow, James R.  
Civelli, Olivier  
Kennedy, James  
Seeman, Phillip  
Niznik, Hyman B.  
Jovanovic, Vera

(B) TITLE: Multiple dopamine D4 receptor variants in the human population

(C) JOURNAL: Nature

(D) VOLUME: 358

(F) PAGES: 149-152

(G) DATE: 9 JULY-1992

## (x) PUBLICATION INFORMATION:

(A) AUTHORS: Van Tol, Hubert H.M.

Bunzow, James R.  
Guan, Hong-Chang  
Sunahara, Roger K.  
Seeman, Phillip  
Niznik, Hyman B.  
Civelli, Olivier

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 1:

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CGGGGGCGGG ACCAGGTCC GGCCGGGGCG TGCCCCGGG GAGGGACTCC CCGGCTTGCC      60
CCCCGGCGTT GTCCGCGGTG CTCAGCGCCC GCCCGGGCGC GCC ATG GGG AAC CGC      115
                                     Met Gly Asn Arg
                                     1
AGC ACC GCG GAC GCG GAC GGG CTG CTG GCT GGG CGC GGG CGG GCC GCG      163
Ser Thr Ala Asp Ala Asp Gly Leu Leu Ala Gly Arg Gly Arg Ala Ala
   5                10                15                20
GGG GCA TCT GCG GGG GCA TCT GCG GGG CTG GCT GGG CAG GGC GCG GCG      211
Gly Ala Ser Ala Gly Ala Ser Ala Gly Leu Ala Gly Gln Gly Ala Ala
   25                30                35
GCG CTG GTG GGG GGC GTG CTG CTC ATC GGC GCG GTG CTC GCG GGG AAC      259
Ala Leu Val Gly Gly Val Leu Leu Ile Gly Ala Val Leu Ala Gly Asn
   40                45                50

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-continued

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TCG CTC GTG TGC GTG AGC GTG GCC ACC GAG CGC GCC CTG CAG ACG CCC 307  
 Ser Leu Val Cys Val Ser Val Ala Thr Glu Arg Ala Leu Gln Thr Pro  
           55                          60                          65

ACC AAC TCC TTC ATC GTG AGC CTG GCG GCC GCC GAC CTC CTC CTC GCT 355  
 Thr Asn Ser Phe Ile Val Ser Leu Ala Ala Ala Asp Leu Leu Leu Ala  
           70                          75                          80

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 Leu Leu Val Leu Pro Leu Phe Val Tyr Ser Glu  
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 (A) LENGTH: 95 amino acids  
 (B) TYPE: amino acid  
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 2:

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 1                  5                          10                          15

Gly Arg Ala Ala Gly Ala Ser Ala Gly Ala Ser Ala Gly Leu Ala Gly  
                   20                          25                          30

Gln Gly Ala Ala Ala Leu Val Gly Gly Val Leu Leu Ile Gly Ala Val  
                   35                          40                          45

Leu Ala Gly Asn Ser Leu Val Cys Val Ser Val Ala Thr Glu Arg Ala  
           50                          55                          60

Leu Gln Thr Pro Thr Asn Ser Phe Ile Val Ser Leu Ala Ala Ala Asp  
           65                          70                          75                          80

Leu Leu Leu Ala Leu Leu Val Leu Pro Leu Phe Val Tyr Ser Glu  
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- (i) SEQUENCE CHARACTERISTICS:  
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 (B) TYPE: nucleic acid  
 (C) STRANDEDNESS: single  
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

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 (B) LOCATION: 1..20  
 (C) IDENTIFICATION METHOD: experimental  
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                           /note= "This is the 5' sequence of an intron  
                           estimated to be 2.0 kilobases in length"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 3:

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20

## (2) INFORMATION FOR SEQ ID NO: 4:

- (i) SEQUENCE CHARACTERISTICS:  
 (A) LENGTH: 20 base pairs  
 (B) TYPE: nucleic acid  
 (C) STRANDEDNESS: single  
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

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- (ix) FEATURE:  
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 (B) LOCATION: 1..20  
 (C) IDENTIFICATION METHOD: experimental  
 (D) OTHER INFORMATION: /partial  
     /cons\_splice= (5'site: NO, 3'site: YES)  
     /evidence= EXPERIMENTAL  
     /label= IntronI  
     /note= "This is the 3' sequence of a intron  
     estimated to be 2.0 kilobases in length."

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 4:

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- (2) INFORMATION FOR SEQ ID NO: 5:

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 (A) LENGTH: 113 base pairs  
 (B) TYPE: nucleic acid  
 (C) STRANDEDNESS: single  
 (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

- (ix) FEATURE:  
 (A) NAME/KEY: exon  
 (B) LOCATION: 1..113

- (ix) FEATURE:  
 (A) NAME/KEY: CDS  
 (B) LOCATION: 1..113

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 5:

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 1 5 10 15

ATG GCC ATG GAC GTC ATG CTG TGC ACC GCC TCC ATC TTC AAC CTG TGC 96  
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 20 25 30

GCC ATC AGC GTG GAC AG 113  
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 35

- (2) INFORMATION FOR SEQ ID NO: 6:

- (i) SEQUENCE CHARACTERISTICS:  
 (A) LENGTH: 37 amino acids  
 (B) TYPE: amino acid  
 (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: protein

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 6:

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Ala Ile Ser Val Asp  
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- (2) INFORMATION FOR SEQ ID NO: 7:

- (i) SEQUENCE CHARACTERISTICS:  
 (A) LENGTH: 102 base pairs  
 (B) TYPE: nucleic acid  
 (C) STRANDEDNESS: single  
 (D) TOPOLOGY: linear

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(ii) MOLECULE TYPE: DNA (genomic)

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- (B) LOCATION: 1..102
- (C) IDENTIFICATION METHOD: experimental
- (D) OTHER INFORMATION: /evidence= EXPERIMENTAL  
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(2) INFORMATION FOR SEQ ID NO: 8:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 563 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

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- (A) NAME/KEY: exon
- (B) LOCATION: 1..563
- (C) IDENTIFICATION METHOD: experimental
- (D) OTHER INFORMATION: /evidence= EXPERIMENTAL  
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- (C) IDENTIFICATION METHOD: experimental
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(ix) FEATURE:

- (A) NAME/KEY: repeat\_region
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- (D) OTHER INFORMATION: /rpt\_type= "tandem"  
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/note= "This sequence represents one of 7 known  
alleles of human D4 dopamine receptor gene  
encoding a 16 amino acid sequence repeated twice

(ix) FEATURE:

- (A) NAME/KEY: CDS
- (B) LOCATION: 2..563

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 8:

G TTC GTG GCC GTG GCC GTG CCG CTG CGC TAC AAC CGG CAG GGT GGG 46  
Phe Val Ala Val Ala Val Pro Leu Arg Tyr Asn Arg Gln Gly Gly  
1 5 10 15

AGC CGC CGG CAG CTG CTG CTC ATC GGC GCC ACG TGG CTG CTG TCC GCG 94  
Ser Arg Arg Gln Leu Leu Leu Ile Gly Ala Thr Trp Leu Leu Ser Ala  
20 25 30

GCG GTG GCG GCG CCC GTA CTG TGC GGC CTC AAC GAC GTG CGC GGC CGC 142  
Ala Val Ala Ala Pro Val Leu Cys Gly Leu Asn Asp Val Arg Gly Arg  
35 40 45

GAC CCC GCC GTG TGC CGC CTG GAG GAC CGC GAC TAC GTG GTC TAC TCG 190  
Asp Pro Ala Val Cys Arg Leu Glu Asp Arg Asp Tyr Val Val Tyr Ser  
50 55 60

TCC GTG TGC TCC TTC TTC CTA CCC TGC CCG CTC ATG CTG CTG CTG TAC 238



-continued

Ser	Val	Cys	Ser	Phe	Phe	Leu	Pro	Cys	Pro	Leu	Met	Leu	Leu	Leu	Tyr	
	65					70					75					
TGG	GCC	ACG	TTC	CGC	GGC	CTG	CAG	CGC	TGG	GAG	GTG	GCA	CGT	CGC	GCC	286
Trp	Ala	Thr	Phe	Arg	Gly	Leu	Gln	Arg	Trp	Glu	Val	Ala	Arg	Arg	Ala	
	80				85					90					95	
AAG	CTG	CAC	GGC	CGC	GCG	CCC	CGC	CGA	CCC	AGC	GGC	CCT	GGC	CCG	CCT	334
Lys	Leu	His	Gly	Arg	Ala	Pro	Arg	Arg	Pro	Ser	Gly	Pro	Gly	Pro	Pro	
				100					105					110		
TCC	CCC	ACG	CCA	CCC	GCG	CCC	CGC	CTC	CCC	CAG	GAC	CCC	TGC	GGC	CCC	382
Ser	Pro	Thr	Pro	Pro	Ala	Pro	Arg	Leu	Pro	Gln	Asp	Pro	Cys	Gly	Pro	
			115					120					125			
GAC	TGT	GCG	CCC	CCC	GCG	CCC	GGC	CTC	CCC	CCG	GAC	CCC	TGC	GGC	TCC	430
Asp	Cys	Ala	Pro	Pro	Ala	Pro	Gly	Leu	Pro	Pro	Asp	Pro	Cys	Gly	Ser	
		130					135						140			
AAC	TGT	GCT	CCC	CCC	GAC	GCC	GTC	AGA	GCC	GCC	GCG	CTC	CCA	CCC	CAG	478
Asn	Cys	Ala	Pro	Pro	Asp	Ala	Val	Arg	Ala	Ala	Ala	Leu	Pro	Pro	Gln	
	145					150					155					
ACT	CCA	CCG	CAG	ACC	CGC	AGG	AGG	CGG	CGT	GCC	AAG	ATC	ACC	GGC	CGG	526
Thr	Pro	Pro	Gln	Thr	Arg	Arg	Arg	Arg	Arg	Ala	Lys	Ile	Thr	Gly	Arg	
	160				165					170					175	
GAG	CGC	AAG	GCC	ATG	AGG	GTC	CTG	CCG	GTG	GTG	GTC	G				563
Glu	Arg	Lys	Ala	Met	Arg	Val	Leu	Pro	Val	Val	Val					
				180						185						

(2) INFORMATION FOR SEQ ID NO: 9:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 187 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 9:

Phe	Val	Ala	Val	Ala	Val	Pro	Leu	Arg	Tyr	Asn	Arg	Gln	Gly	Gly	Ser	
1				5					10					15		
Arg	Arg	Gln	Leu	Leu	Leu	Ile	Gly	Ala	Thr	Trp	Leu	Leu	Ser	Ala	Ala	
		20						25					30			
Val	Ala	Ala	Pro	Val	Leu	Cys	Gly	Leu	Asn	Asp	Val	Arg	Gly	Arg	Asp	
		35					40					45				
Pro	Ala	Val	Cys	Arg	Leu	Glu	Asp	Arg	Asp	Tyr	Val	Val	Tyr	Ser	Ser	
		50				55					60					
Val	Cys	Ser	Phe	Phe	Leu	Pro	Cys	Pro	Leu	Met	Leu	Leu	Leu	Tyr	Trp	
		65			70					75					80	
Ala	Thr	Phe	Arg	Gly	Leu	Gln	Arg	Trp	Glu	Val	Ala	Arg	Arg	Ala	Lys	
				85					90					95		
Leu	His	Gly	Arg	Ala	Pro	Arg	Arg	Pro	Ser	Gly	Pro	Gly	Pro	Pro	Ser	
			100					105						110		
Pro	Thr	Pro	Pro	Ala	Pro	Arg	Leu	Pro	Gln	Asp	Pro	Cys	Gly	Pro	Asp	
		115					120						125			
Cys	Ala	Pro	Pro	Ala	Pro	Gly	Leu	Pro	Pro	Asp	Pro	Cys	Gly	Ser	Asn	
		130				135						140				
Cys	Ala	Pro	Pro	Asp	Ala	Val	Arg	Ala	Ala	Ala	Leu	Pro	Pro	Gln	Thr	
		145			150					155					160	
Pro	Pro	Gln	Thr	Arg	Arg	Arg	Arg	Arg	Ala	Lys	Ile	Thr	Gly	Arg	Glu	
				165					170					175		
Arg	Lys	Ala	Met	Arg	Val	Leu	Pro	Val	Val	Val						
			180							185						

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## (2) INFORMATION FOR SEQ ID NO: 10:

## (i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 659 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

## (ii) MOLECULE TYPE: DNA (genomic)

## (ix) FEATURE:

- (A) NAME/KEY: exon
- (B) LOCATION: 1..659
- (C) IDENTIFICATION METHOD: experimental
- (D) OTHER INFORMATION: /evidence= EXPERIMENTAL  
/standard\_name= "Alternate Exon 3: D4.4"  
/note= "This sequence represents the third exon of allele D4.4 of the human D4 dopamine receptor gene"

## (ix) FEATURE:

- (A) NAME/KEY: misc\_feature
- (B) LOCATION: 257..262
- (C) IDENTIFICATION METHOD: experimental
- (D) OTHER INFORMATION: /function= "PstI site"  
/evidence= EXPERIMENTAL  
/standard\_name= "PstI site"  
/label= PstI  
/note= "This sequence represents a polymorphic PstI site whereby digestion of human genomic DNA produces a RFLP "

## (ix) FEATURE:

- (A) NAME/KEY: repeat\_region
- (B) LOCATION: 346..538
- (C) IDENTIFICATION METHOD: experimental
- (D) OTHER INFORMATION: /rpt\_type= "tandem"  
/evidence= EXPERIMENTAL  
/rpt\_unit= 348 .. 396  
/note= "This repeat is present in 7 known alleles of the human D4 dopamine receptor gene and encodes a 16 amino acid sequence repeated 4 times in the

## (ix) FEATURE:

- (A) NAME/KEY: CDS
- (B) LOCATION: 2..659

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 10:

```

G TTC GTG GCC GTG GCC GTG CCG CTG CGC TAC AAC CGG CAG GGT GGG      46
Phe Val Ala Val Ala Val Pro Leu Arg Tyr Asn Arg Gln Gly Gly
  1             5             10             15

AGC CGC CGG CAG CTG CTG CTC ATC GGC GCC ACG TGG CTG CTG TCC GCG      94
Ser Arg Arg Gln Leu Leu Leu Ile Gly Ala Thr Trp Leu Leu Ser Ala
             20             25             30

GCG GTG GCG GCG CCC GTA CTG TGC GGC CTC AAC GAC GTG CGC GGC CGC      142
Ala Val Ala Ala Pro Val Leu Cys Gly Leu Asn Asp Val Arg Gly Arg
             35             40             45

GAC CCC GCC GTG TGC CGC CTG GAG GAC CGC GAC TAC GTG GTC TAC TCG      190
Asp Pro Ala Val Cys Arg Leu Glu Asp Arg Asp Tyr Val Val Tyr Ser
             50             55             60

TCC GTG TGC TCC TTC TTC CTA CCC TGC CCG CTC ATG CTG CTG CTG TAC      238
Ser Val Cys Ser Phe Phe Leu Pro Cys Pro Leu Met Leu Leu Leu Tyr
             65             70             75

TGG GCC ACG TTC CGC GGC CTG CAG CGC TGG GAG GTG GCA CGT CGC GCC      286
Trp Ala Thr Phe Arg Gly Leu Gln Arg Trp Glu Val Ala Arg Arg Ala
             80             85             90             95

AAG CTG CAC GGC CGC GCG CCC CGC CGA CCC AGC GGC CCT GGC CCG CCT      334
Lys Leu His Gly Arg Ala Pro Arg Arg Pro Ser Gly Pro Gly Pro Pro
             100            105            110

TCC CCC ACG CCA CCC GCG CCC CGC CTC CCC CAG GAC CCC TGC GGC CCC      382

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Ser	Pro	Thr	Pro	Pro	Ala	Pro	Arg	Leu	Pro	Gln	Asp	Pro	Cys	Gly	Pro	
			115					120					125			
GAC	TGT	GCG	CCC	CCC	GCG	CCC	GGC	CTT	CCC	CGG	GGT	CCC	TGC	GGC	CCC	430
Asp	Cys	Ala	Pro	Pro	Ala	Pro	Gly	Leu	Pro	Arg	Gly	Pro	Cys	Gly	Pro	
		130					135					140				
GAC	TGT	GCG	CCC	GCC	GCG	CCC	AGC	CTC	CCC	CAG	GAC	CCC	TGC	GGC	CCC	478
Asp	Cys	Ala	Pro	Ala	Ala	Pro	Ser	Leu	Pro	Gln	Asp	Pro	Cys	Gly	Pro	
		145				150					155					
GAC	TGT	GCG	CCC	CCC	GCG	CCC	GGC	CTC	CCC	CCG	GAC	CCC	TGC	GGC	TCC	526
Asp	Cys	Ala	Pro	Pro	Ala	Pro	Gly	Leu	Pro	Pro	Asp	Pro	Cys	Gly	Ser	
		160			165					170					175	
AAC	TGT	GCT	CCC	CCC	GAC	GCC	GTC	AGA	GCC	GCC	GCG	CTC	CCA	CCC	CAG	574
Asn	Cys	Ala	Pro	Pro	Asp	Ala	Val	Arg	Ala	Ala	Ala	Leu	Pro	Pro	Gln	
			180						185					190		
ACT	CCA	CCG	CAG	ACC	CGC	AGG	AGG	CGG	CGT	GCC	AAG	ATC	ACC	GGC	CGG	622
Thr	Pro	Pro	Gln	Thr	Arg	Arg	Arg	Arg	Arg	Ala	Lys	Ile	Thr	Gly	Arg	
			195					200					205			
GAG	CGC	AAG	GCC	ATG	AGG	GTC	CTG	CCG	GTG	GTG	GTC	G				659
Glu	Arg	Lys	Ala	Met	Arg	Val	Leu	Pro	Val	Val	Val					
		210					215									

(2) INFORMATION FOR SEQ ID NO: 11:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 219 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 11:

Phe	Val	Ala	Val	Ala	Val	Pro	Leu	Arg	Tyr	Asn	Arg	Gln	Gly	Gly	Ser	
1				5					10					15		
Arg	Arg	Gln	Leu	Leu	Leu	Ile	Gly	Ala	Thr	Trp	Leu	Leu	Ser	Ala	Ala	
		20						25					30			
Val	Ala	Ala	Pro	Val	Leu	Cys	Gly	Leu	Asn	Asp	Val	Arg	Gly	Arg	Asp	
		35					40					45				
Pro	Ala	Val	Cys	Arg	Leu	Glu	Asp	Arg	Asp	Tyr	Val	Val	Tyr	Ser	Ser	
		50				55					60					
Val	Cys	Ser	Phe	Phe	Leu	Pro	Cys	Pro	Leu	Met	Leu	Leu	Leu	Tyr	Trp	
		65			70					75					80	
Ala	Thr	Phe	Arg	Gly	Leu	Gln	Arg	Trp	Glu	Val	Ala	Arg	Arg	Ala	Lys	
				85					90					95		
Leu	His	Gly	Arg	Ala	Pro	Arg	Arg	Pro	Ser	Gly	Pro	Gly	Pro	Pro	Ser	
			100					105					110			
Pro	Thr	Pro	Pro	Ala	Pro	Arg	Leu	Pro	Gln	Asp	Pro	Cys	Gly	Pro	Asp	
		115					120						125			
Cys	Ala	Pro	Pro	Ala	Pro	Gly	Leu	Pro	Arg	Gly	Pro	Cys	Gly	Pro	Asp	
		130				135					140					
Cys	Ala	Pro	Ala	Ala	Pro	Ser	Leu	Pro	Gln	Asp	Pro	Cys	Gly	Pro	Asp	
		145			150					155					160	
Cys	Ala	Pro	Pro	Ala	Pro	Gly	Leu	Pro	Pro	Asp	Pro	Cys	Gly	Ser	Asn	
			165						170					175		
Cys	Ala	Pro	Pro	Asp	Ala	Val	Arg	Ala	Ala	Ala	Leu	Pro	Pro	Gln	Thr	
		180						185						190		
Pro	Pro	Gln	Thr	Arg	Arg	Arg	Arg	Arg	Ala	Lys	Ile	Thr	Gly	Arg	Glu	
		195					200						205			
Arg	Lys	Ala	Met	Arg	Val	Leu	Pro	Val	Val	Val						

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215

## (2) INFORMATION FOR SEQ ID NO: 12:

## (i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 803 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

## (ii) MOLECULE TYPE: DNA (genomic)

## (ix) FEATURE:

- (A) NAME/KEY: exon
- (B) LOCATION: 1..803
- (C) IDENTIFICATION METHOD: experimental
- (D) OTHER INFORMATION: /evidence= EXPERIMENTAL  
/standard\_name= "Alternate Exon 3: D4.7"  
/note= "This sequence represents the third exon of allele D4.7 of the human D4 dopamine receptor gene"

## (ix) FEATURE:

- (A) NAME/KEY: misc\_feature
- (B) LOCATION: 257..262
- (C) IDENTIFICATION METHOD: experimental
- (D) OTHER INFORMATION: /function= "PstI site"  
/evidence= EXPERIMENTAL  
/standard\_name= "PstI site"  
/label= PstI  
/note= "This sequence is a PstI site whereby digestion of human genomic DNA produces a RFLP"

## (ix) FEATURE:

- (A) NAME/KEY: repeat\_region
- (B) LOCATION: 346..682
- (C) IDENTIFICATION METHOD: experimental
- (D) OTHER INFORMATION: /rpt\_type= "tandem"  
/evidence= EXPERIMENTAL  
/rpt\_unit= 346 .. 394  
/note= "This sequence is a repeat found in 7 known alleles of the human D4 dopamine receptor gene encoding a 16 amino acid sequence repeated 7 times"

## (ix) FEATURE:

- (A) NAME/KEY: CDS
- (B) LOCATION: 2..803

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 12:

```

G TTC GTG GCC GTG GCC GTG CCG CTG CGC TAC AAC CGG CAG GGT GGG      46
Phe Val Ala Val Ala Val Pro Leu Arg Tyr Asn Arg Gln Gly Gly
  1             5             10             15

AGC CGC CGG CAG CTG CTG CTC ATC GGC GCC ACG TGG CTG CTG TCC GCG      94
Ser Arg Arg Gln Leu Leu Leu Ile Gly Ala Thr Trp Leu Leu Ser Ala
             20             25             30

GCG GTG GCG GCG CCC GTA CTG TGC GGC CTC AAC GAC GTG CGC GGC CGC      142
Ala Val Ala Ala Pro Val Leu Cys Gly Leu Asn Asp Val Arg Gly Arg
             35             40             45

GAC CCC GCC GTG TGC CGC CTG GAG GAC CGC GAC TAC GTG GTC TAC TCG      190
Asp Pro Ala Val Cys Arg Leu Glu Asp Arg Asp Tyr Val Val Tyr Ser
             50             55             60

TCC GTG TGC TCC TTC TTC CTA CCC TGC CCG CTC ATG CTG CTG CTG TAC      238
Ser Val Cys Ser Phe Phe Leu Pro Cys Pro Leu Met Leu Leu Leu Tyr
             65             70             75

TGG GCC ACG TTC CGC GGC CTG CAG CGC TGG GAG GTG GCA CGT CGC GCC      286
Trp Ala Thr Phe Arg Gly Leu Gln Arg Trp Glu Val Ala Arg Arg Ala
             80             85             90             95

AAG CTG CAC GGC CGC GCG CCC CGC CGA CCC AGC GGC CCT GGC CCG CCT      334
Lys Leu His Gly Arg Ala Pro Arg Arg Pro Ser Gly Pro Gly Pro Pro
             100             105             110

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TCC	CCC	ACG	CCA	CCC	GCG	CCC	CGC	CTC	CCC	CAG	GAC	CCC	TGC	GGC	CCC	382
Ser	Pro	Thr	Pro	Pro	Ala	Pro	Arg	Leu	Pro	Gln	Asp	Pro	Cys	Gly	Pro	
			115					120					125			
GAC	TGT	GCG	CCC	CCC	GCG	CCC	GGC	CTT	CCC	CGG	GGT	CCC	TGC	GGC	CCC	430
Asp	Cys	Ala	Pro	Pro	Ala	Pro	Gly	Leu	Pro	Arg	Gly	Pro	Cys	Gly	Pro	
		130					135					140				
GAC	TGT	GCG	CCC	GCC	GCG	CCC	GGC	CTC	CCC	CCG	GAC	CCC	TGC	GGC	CCC	478
Asp	Cys	Ala	Pro	Ala	Ala	Pro	Gly	Leu	Pro	Pro	Asp	Pro	Cys	Gly	Pro	
		145				150					155					
GAC	TGT	GCG	CCC	CCC	GCG	CCC	GGC	CTC	CCC	CAG	GAC	CCC	TGC	GGC	CCC	526
Asp	Cys	Ala	Pro	Pro	Ala	Pro	Gly	Leu	Pro	Gln	Asp	Pro	Cys	Gly	Pro	
160					165					170					175	
GAC	TGT	GCG	CCC	CCC	GCG	CCC	GGC	CTT	CCC	CGG	GGT	CCC	TGC	GGC	CCC	574
Asp	Cys	Ala	Pro	Pro	Ala	Pro	Gly	Leu	Pro	Arg	Gly	Pro	Cys	Gly	Pro	
			180						185					190		
GAC	TGT	GCG	CCC	CCC	GCG	CCC	GGC	CTC	CCC	CAG	GAC	CCC	TGC	GGC	CCC	622
Asp	Cys	Ala	Pro	Pro	Ala	Pro	Gly	Leu	Pro	Gln	Asp	Pro	Cys	Gly	Pro	
		195						200					205			
GAC	TGT	GCG	CCC	CCC	GCG	CCC	GGC	CTC	CCC	CCG	GAC	CCC	TGC	GGC	TCC	670
Asp	Cys	Ala	Pro	Pro	Ala	Pro	Gly	Leu	Pro	Pro	Asp	Pro	Cys	Gly	Ser	
		210					215					220				
AAC	TGT	GCT	CCC	CCC	GAC	GCC	GTC	AGA	GCC	GCC	GCG	CTC	CCA	CCC	CAG	718
Asn	Cys	Ala	Pro	Pro	Asp	Ala	Val	Arg	Ala	Ala	Ala	Leu	Pro	Pro	Gln	
		225				230					235					
ACT	CCA	CCG	CAG	ACC	CGC	AGG	AGG	CGG	CGT	GCC	AAG	ATC	ACC	GGC	CGG	766
Thr	Pro	Pro	Gln	Thr	Arg	Arg	Arg	Arg	Arg	Ala	Lys	Ile	Thr	Gly	Arg	
240					245					250					255	
GAG	CGC	AAG	GCC	ATG	AGG	GTC	CTG	CCG	GTG	GTG	GTC	G				803
Glu	Arg	Lys	Ala	Met	Arg	Val	Leu	Pro	Val	Val	Val					
			260						265							

(2) INFORMATION FOR SEQ ID NO: 13:

- (i) SEQUENCE CHARACTERISTICS:
  - (A) LENGTH: 267 amino acids
  - (B) TYPE: amino acid
  - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 13:

Phe	Val	Ala	Val	Ala	Val	Pro	Leu	Arg	Tyr	Asn	Arg	Gln	Gly	Gly	Ser	
1				5					10					15		
Arg	Arg	Gln	Leu	Leu	Leu	Ile	Gly	Ala	Thr	Trp	Leu	Leu	Ser	Ala	Ala	
		20						25					30			
Val	Ala	Ala	Pro	Val	Leu	Cys	Gly	Leu	Asn	Asp	Val	Arg	Gly	Arg	Asp	
		35					40					45				
Pro	Ala	Val	Cys	Arg	Leu	Glu	Asp	Arg	Asp	Tyr	Val	Val	Tyr	Ser	Ser	
		50				55					60					
Val	Cys	Ser	Phe	Phe	Leu	Pro	Cys	Pro	Leu	Met	Leu	Leu	Leu	Tyr	Trp	
65					70					75					80	
Ala	Thr	Phe	Arg	Gly	Leu	Gln	Arg	Trp	Glu	Val	Ala	Arg	Arg	Ala	Lys	
				85					90					95		
Leu	His	Gly	Arg	Ala	Pro	Arg	Arg	Pro	Ser	Gly	Pro	Gly	Pro	Pro	Ser	
			100					105					110			
Pro	Thr	Pro	Pro	Ala	Pro	Arg	Leu	Pro	Gln	Asp	Pro	Cys	Gly	Pro	Asp	
		115					120					125				
Cys	Ala	Pro	Pro	Ala	Pro	Gly	Leu	Pro	Arg	Gly	Pro	Cys	Gly	Pro	Asp	
		130				135					140					

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Cys Ala Pro Ala Ala Pro Gly Leu Pro Pro Asp Pro Cys Gly Pro Asp  
 145 150 155 160

Cys Ala Pro Pro Ala Pro Gly Leu Pro Gln Asp Pro Cys Gly Pro Asp  
 165 170 175

Cys Ala Pro Pro Ala Pro Gly Leu Pro Arg Gly Pro Cys Gly Pro Asp  
 180 185 190

Cys Ala Pro Pro Ala Pro Gly Leu Pro Gln Asp Pro Cys Gly Pro Asp  
 195 200 205

Cys Ala Pro Pro Ala Pro Gly Leu Pro Pro Asp Pro Cys Gly Ser Asn  
 210 215 220

Cys Ala Pro Pro Asp Ala Val Arg Ala Ala Ala Leu Pro Pro Gln Thr  
 225 230 235 240

Pro Pro Gln Thr Arg Arg Arg Arg Arg Ala Lys Ile Thr Gly Arg Glu  
 245 250 255

Arg Lys Ala Met Arg Val Leu Pro Val Val Val  
 260 265

## (2) INFORMATION FOR SEQ ID NO: 14:

- (i) SEQUENCE CHARACTERISTICS:  
 (A) LENGTH: 94 base pairs  
 (B) TYPE: nucleic acid  
 (C) STRANDEDNESS: single  
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

- (ix) FEATURE:  
 (A) NAME/KEY: intron  
 (B) LOCATION: 1..94

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 14:

GTGGGTTTCCT GTCCTGAGGG GCGGGGAGGA GAGGAGGGGG GGAGTACGAG GCCGGCTGGG 60  
 CGGGGGGCGC TAACGCGGCT CTCGGCGCCC CCAG 94

## (2) INFORMATION FOR SEQ ID NO: 15:

- (i) SEQUENCE CHARACTERISTICS:  
 (A) LENGTH: 328 base pairs  
 (B) TYPE: nucleic acid  
 (C) STRANDEDNESS: single  
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

- (ix) FEATURE:  
 (A) NAME/KEY: exon  
 (B) LOCATION: 1..328

- (ix) FEATURE:  
 (A) NAME/KEY: CDS  
 (B) LOCATION: 3..203

- (ix) FEATURE:  
 (A) NAME/KEY: 3'UTR  
 (B) LOCATION: 204..328

- (ix) FEATURE:  
 (A) NAME/KEY: polyA\_site  
 (B) LOCATION: 304

- (ix) FEATURE:  
 (A) NAME/KEY: misc\_feature  
 (B) LOCATION: 36..41  
 (C) IDENTIFICATION METHOD: experimental  
 (D) OTHER INFORMATION: /function= "HincII site"  
 /evidence= EXPERIMENTAL  
 /standard\_name= "HincII site"



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/label= HinCII  
 /note= "This sequence is a HinCII site whereby  
 digestion of genomic DNA produces a RFLP"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 15:

```

GG GCC TTC CTG CTG TGC TGG ACG CCC TTC TTC GTG GTG CAC ATC ACG      47
  Ala Phe Leu Leu Cys Trp Thr Pro Phe Phe Val Val His Ile Thr
    1             5             10             15

CAG GCG CTG TGT CCT GCC TGC TCC GTG CCC CCG CGG CTG GTC AGC GCC      95
  Gln Ala Leu Cys Pro Ala Cys Ser Val Pro Pro Arg Leu Val Ser Ala
                20             25             30

GTC ACC TGG CTG GGC TAC GTC AAC AGC GCC CTC ACC CCC GTC ATC TAC     143
  Val Thr Trp Leu Gly Tyr Val Asn Ser Ala Leu Thr Pro Val Ile Tyr
    35             40             45

ACT GTC TTC AAC GCC GAG TTC CGC AAC GTC TTC CGC AAG GCC CTG CGT     191
  Thr Val Phe Asn Ala Glu Phe Arg Asn Val Phe Arg Lys Ala Leu Arg
    50             55             60

GCC TGC TGC TGAGCCGGGC ACCCCCGGAC GCCCCCGGC CTGATGGCCA             240
  Ala Cys Cys
    65

GGCCTCAGGG ACCAAGGAGA TGGGGAGGGC GCTTTTGTAC GTTAATTAAA CAAATTCCTT  300

CCCAAACCTCA GCTGTGAAGG CTCCTGGG                                 328
  
```

(2) INFORMATION FOR SEQ ID NO: 16:

(i) SEQUENCE CHARACTERISTICS:  
 (A) LENGTH: 66 amino acids  
 (B) TYPE: amino acid  
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 16:

```

Ala Phe Leu Leu Cys Trp Thr Pro Phe Phe Val Val His Ile Thr Gln
  1             5             10             15

Ala Leu Cys Pro Ala Cys Ser Val Pro Pro Arg Leu Val Ser Ala Val
    20             25             30

Thr Trp Leu Gly Tyr Val Asn Ser Ala Leu Thr Pro Val Ile Tyr Thr
    35             40             45

Val Phe Asn Ala Glu Phe Arg Asn Val Phe Arg Lys Ala Leu Arg Ala
    50             55             60

Cys Cys
  65
  
```

(2) INFORMATION FOR SEQ ID NO: 17:

(i) SEQUENCE CHARACTERISTICS:  
 (A) LENGTH: 1370 base pairs  
 (B) TYPE: nucleic acid  
 (C) STRANDEDNESS: single  
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(ix) FEATURE:

(A) NAME/KEY: 5'UTR  
 (B) LOCATION: 1..103

(ix) FEATURE:

(A) NAME/KEY: 3'UTR  
 (B) LOCATION: 1268..1370

(ix) FEATURE:

(A) NAME/KEY: CDS  
 (B) LOCATION: 104..1267

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(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 17:

CGGGGGCGGG ACCAGGGTCC GGCCGGGGCG TGCCCCCGGG GAGGGACTCC CCGGCTTGCC	60
CCCCGGCGTT GTCCGCGGTG CTCAGCGCCC GCCCGGGCGC GCC ATG GGG AAC CGC	115
Met Gly Asn Arg	
1	
AGC ACC GCG GAC GCG GAC GGG CTG CTG GCT GGG CGC GGG CGG GCC GCG	163
Ser Thr Ala Asp Ala Asp Gly Leu Leu Ala Gly Arg Gly Arg Ala Ala	
5 10 15 20	
GGG GCA TCT GCG GGG GCA TCT GCG GGG CTG GCT GGG CAG GGC GCG GCG	211
Gly Ala Ser Ala Gly Ala Ser Ala Gly Leu Ala Gly Gln Gly Ala Ala	
25 30 35	
GCG CTG GTG GGG GGC GTG CTG CTC ATC GGC GCG GTG CTC GCG GGG AAC	259
Ala Leu Val Gly Gly Val Leu Leu Ile Gly Ala Val Leu Ala Gly Asn	
40 45 50	
TCG CTC GTG TGC GTG AGC GTG GCC ACC GAG CGC GCC CTG CAG ACG CCC	307
Ser Leu Val Cys Val Ser Val Ala Thr Glu Arg Ala Leu Gln Thr Pro	
55 60 65	
ACC AAC TCC TTC ATC GTG AGC CTG GCG GCC GCC GAC CTC CTC CTC GCT	355
Thr Asn Ser Phe Ile Val Ser Leu Ala Ala Ala Asp Leu Leu Leu Ala	
70 75 80	
CTC CTG GTG CTG CCG CTC TTC GTC TAC TCC GAG GTC CAG GGT GGC GCG	403
Leu Leu Val Leu Pro Leu Phe Val Tyr Ser Glu Val Gln Gly Gly Ala	
85 90 95 100	
TGG CTG CTG AGC CCC CGC CTG TGC GAC GCC CTC ATG GCC ATG GAC GTC	451
Trp Leu Leu Ser Pro Arg Leu Cys Asp Ala Leu Met Ala Met Asp Val	
105 110 115	
ATG CTG TGC ACC GCC TCC ATC TTC AAC CTG TGC GCC ATC AGC GTG GAC	499
Met Leu Cys Thr Ala Ser Ile Phe Asn Leu Cys Ala Ile Ser Val Asp	
120 125 130	
AGG TTC GTG GCC GTG GCC GTG CCG CTG CGC TAC AAC CGG CAG GGT GGG	547
Arg Phe Val Ala Val Ala Val Pro Leu Arg Tyr Asn Arg Gln Gly Gly	
135 140 145	
AGC CGC CGG CAG CTG CTG CTC ATC GGC GCC ACG TGG CTG CTG TCC GCG	595
Ser Arg Arg Gln Leu Leu Leu Ile Gly Ala Thr Trp Leu Leu Ser Ala	
150 155 160	
GCG GTG GCG GCG CCC GTA CTG TGC GGC CTC AAC GAC GTG CGC GGC CGC	643
Ala Val Ala Ala Pro Val Leu Cys Gly Leu Asn Asp Val Arg Gly Arg	
165 170 175 180	
GAC CCC GCC GTG TGC CGC CTG GAG GAC CGC GAC TAC GTG GTC TAC TCG	691
Asp Pro Ala Val Cys Arg Leu Glu Asp Arg Asp Tyr Val Val Tyr Ser	
185 190 195	
TCC GTG TGC TCC TTC TTC CTA CCC TGC CCG CTC ATG CTG CTG CTG TAC	739
Ser Val Cys Ser Phe Phe Leu Pro Cys Pro Leu Met Leu Leu Leu Tyr	
200 205 210	
TGG GCC ACG TTC CGC GGC CTG CAG CGC TGG GAG GTG GCA CGT CGC GCC	787
Trp Ala Thr Phe Arg Gly Leu Gln Arg Trp Glu Val Ala Arg Arg Ala	
215 220 225	
AAG CTG CAC GGC CGC GCG CCC CGC CGA CCC AGC GGC CCT GGC CCG CCT	835
Lys Leu His Gly Arg Ala Pro Arg Arg Pro Ser Gly Pro Gly Pro Pro	
230 235 240	
TCC CCC ACG CCA CCC GCG CCC CGC CTC CCC CAG GAC CCC TGC GGC CCC	883
Ser Pro Thr Pro Pro Ala Pro Arg Leu Pro Gln Asp Pro Cys Gly Pro	
245 250 255 260	
GAC TGT GCG CCC CCC GCG CCC GGC CTC CCC CCG GAC CCC TGC GGC TCC	931
Asp Cys Ala Pro Pro Ala Pro Gly Leu Pro Pro Asp Pro Cys Gly Ser	
265 270 275	
AAC TGT GCT CCC CCC GAC GCC GTC AGA GCC GCC GCG CTC CCA CCC CAG	979
Asn Cys Ala Pro Pro Asp Ala Val Arg Ala Ala Ala Leu Pro Pro Gln	





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195			200			205									
Leu	Leu	Leu	Tyr	Trp	Ala	Thr	Phe	Arg	Gly	Leu	Gln	Arg	Trp	Glu	Val
	210						215				220				
Ala	Arg	Arg	Ala	Lys	Leu	His	Gly	Arg	Ala	Pro	Arg	Arg	Pro	Ser	Gly
	225				230					235					240
Pro	Gly	Pro	Pro	Ser	Pro	Thr	Pro	Pro	Ala	Pro	Arg	Leu	Pro	Gln	Asp
				245						250				255	
Pro	Cys	Gly	Pro	Asp	Cys	Ala	Pro	Pro	Ala	Pro	Gly	Leu	Pro	Pro	Asp
				260				265					270		
Pro	Cys	Gly	Ser	Asn	Cys	Ala	Pro	Pro	Asp	Ala	Val	Arg	Ala	Ala	Ala
							280						285		
Leu	Pro	Pro	Gln	Thr	Pro	Pro	Gln	Thr	Arg	Arg	Arg	Arg	Arg	Ala	Lys
	290						295				300				
Ile	Thr	Gly	Arg	Glu	Arg	Lys	Ala	Met	Arg	Val	Leu	Pro	Val	Val	Val
	305				310					315					320
Gly	Ala	Phe	Leu	Leu	Cys	Trp	Thr	Pro	Phe	Phe	Val	Val	His	Ile	Thr
				325						330				335	
Gln	Ala	Leu	Cys	Pro	Ala	Cys	Ser	Val	Pro	Pro	Arg	Leu	Val	Ser	Ala
				340				345					350		
Val	Thr	Trp	Leu	Gly	Tyr	Val	Asn	Ser	Ala	Leu	Thr	Pro	Val	Ile	Tyr
		355					360					365			
Thr	Val	Phe	Asn	Ala	Glu	Phe	Arg	Asn	Val	Phe	Arg	Lys	Ala	Leu	Arg
							375				380				
Ala	Cys	Cys													
															385

(2) INFORMATION FOR SEQ ID NO: 19:

- (i) SEQUENCE CHARACTERISTICS:
  - (A) LENGTH: 1466 base pairs
  - (B) TYPE: nucleic acid
  - (C) STRANDEDNESS: single
  - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

- (ix) FEATURE:
  - (A) NAME/KEY: 5'UTR
  - (B) LOCATION: 1..103

- (ix) FEATURE:
  - (A) NAME/KEY: 3'UTR
  - (B) LOCATION: 1364..1466

- (ix) FEATURE:
  - (A) NAME/KEY: CDS
  - (B) LOCATION: 104..1363

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 19:

CGGGGGCGGG ACCAGGGTCC GGCCGGGGCG TGCCCCCGGG GAGGGACTCC CCGGCTTGCC	60
CCCCGGCGTT GTCCGCGGTG CTCAGCGCCC GCCCGGGCGC GCC ATG GGG AAC CGC	115
	Met Gly Asn Arg
	1
AGC ACC GCG GAC GCG GAC GGG CTG CTG GCT GGG CGC GGG CGG GCC GCG	163
Ser Thr Ala Asp Ala Asp Gly Leu Leu Ala Gly Arg Gly Arg Ala Ala	
5 10 15 20	
GGG GCA TCT GCG GGG GCA TCT GCG GGG CTG GCT GGG CAG GGC GCG GCG	211
Gly Ala Ser Ala Gly Ala Ser Ala Gly Leu Ala Gly Gln Gly Ala Ala	
25 30 35	
GCG CTG GTG GGG GGC GTG CTG CTC ATC GGC GCG GTG CTC GCG GGG AAC	259
Ala Leu Val Gly Gly Val Leu Leu Ile Gly Ala Val Leu Ala Gly Asn	



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40				45				50								
TCG	CTC	GTG	TGC	GTG	AGC	GTG	GCC	ACC	GAG	CGC	GCC	CTG	CAG	ACG	CCC	307
Ser	Leu	Val	Cys	Val	Ser	Val	Ala	Thr	Glu	Arg	Ala	Leu	Gln	Thr	Pro	
		55					60					65				
ACC	AAC	TCC	TTC	ATC	GTG	AGC	CTG	GCG	GCC	GCC	GAC	CTC	CTC	CTC	GCT	355
Thr	Asn	Ser	Phe	Ile	Val	Ser	Leu	Ala	Ala	Ala	Asp	Leu	Leu	Leu	Ala	
	70					75					80					
CTC	CTG	GTG	CTG	CCG	CTC	TTC	GTC	TAC	TCC	GAG	GTC	CAG	GGT	GGC	GCG	403
Leu	Leu	Val	Leu	Pro	Leu	Phe	Val	Tyr	Ser	Glu	Val	Gln	Gly	Gly	Ala	
	85				90					95					100	
TGG	CTG	CTG	AGC	CCC	CGC	CTG	TGC	GAC	GCC	CTC	ATG	GCC	ATG	GAC	GTC	451
Trp	Leu	Leu	Ser	Pro	Arg	Leu	Cys	Asp	Ala	Leu	Met	Ala	Met	Asp	Val	
				105					110					115		
ATG	CTG	TGC	ACC	GCC	TCC	ATC	TTC	AAC	CTG	TGC	GCC	ATC	AGC	GTG	GAC	499
Met	Leu	Cys	Thr	Ala	Ser	Ile	Phe	Asn	Leu	Cys	Ala	Ile	Ser	Val	Asp	
			120					125					130			
AGG	TTC	GTG	GCC	GTG	GCC	GTG	CCG	CTG	CGC	TAC	AAC	CGG	CAG	GGT	GGG	547
Arg	Phe	Val	Ala	Val	Ala	Val	Pro	Leu	Arg	Tyr	Asn	Arg	Gln	Gly	Gly	
		135					140					145				
AGC	CGC	CGG	CAG	CTG	CTG	CTC	ATC	GGC	GCC	ACG	TGG	CTG	CTG	TCC	GCG	595
Ser	Arg	Arg	Gln	Leu	Leu	Leu	Ile	Gly	Ala	Thr	Trp	Leu	Leu	Ser	Ala	
	150					155					160					
GCG	GTG	GCG	GCG	CCC	GTA	CTG	TGC	GGC	CTC	AAC	GAC	GTG	CGC	GGC	CGC	643
Ala	Val	Ala	Ala	Pro	Val	Leu	Cys	Gly	Leu	Asn	Asp	Val	Arg	Gly	Arg	
	165				170					175					180	
GAC	CCC	GCC	GTG	TGC	CGC	CTG	GAG	GAC	CGC	GAC	TAC	GTG	GTC	TAC	TCG	691
Asp	Pro	Ala	Val	Cys	Arg	Leu	Glu	Asp	Arg	Asp	Tyr	Val	Val	Tyr	Ser	
				185				190						195		
TCC	GTG	TGC	TCC	TTC	TTC	CTA	CCC	TGC	CCG	CTC	ATG	CTG	CTG	CTG	TAC	739
Ser	Val	Cys	Ser	Phe	Phe	Leu	Pro	Cys	Pro	Leu	Met	Leu	Leu	Leu	Tyr	
			200					205					210			
TGG	GCC	ACG	TTC	CGC	GGC	CTG	CAG	CGC	TGG	GAG	GTG	GCA	CGT	CGC	GCC	787
Trp	Ala	Thr	Phe	Arg	Gly	Leu	Gln	Arg	Trp	Glu	Val	Ala	Arg	Arg	Ala	
		215					220					225				
AAG	CTG	CAC	GGC	CGC	GCG	CCC	CGC	CGA	CCC	AGC	GGC	CCT	GGC	CCG	CCT	835
Lys	Leu	His	Gly	Arg	Ala	Pro	Arg	Arg	Pro	Ser	Gly	Pro	Gly	Pro	Pro	
	230					235					240					
TCC	CCC	ACG	CCA	CCC	GCG	CCC	CGC	CTC	CCC	CAG	GAC	CCC	TGC	GGC	CCC	883
Ser	Pro	Thr	Pro	Pro	Ala	Pro	Arg	Leu	Pro	Gln	Asp	Pro	Cys	Gly	Pro	
	245				250					255					260	
GAC	TGT	GCG	CCC	CCC	GCG	CCC	GGC	CTT	CCC	CGG	GGT	CCC	TGC	GGC	CCC	931
Asp	Cys	Ala	Pro	Pro	Ala	Pro	Gly	Leu	Pro	Arg	Gly	Pro	Cys	Gly	Pro	
				265					270					275		
GAC	TGT	GCG	CCC	GCC	GCG	CCC	AGC	CTC	CCC	CAG	GAC	CCC	TGC	GGC	CCC	979
Asp	Cys	Ala	Pro	Ala	Ala	Pro	Ser	Leu	Pro	Gln	Asp	Pro	Cys	Gly	Pro	
				280				285						290		
GAC	TGT	GCG	CCC	CCC	GCG	CCC	GGC	CTC	CCC	CCG	GAC	CCC	TGC	GGC	TCC	1027
Asp	Cys	Ala	Pro	Pro	Ala	Pro	Gly	Leu	Pro	Pro	Asp	Pro	Cys	Gly	Ser	
		295				300						305				
AAC	TGT	GCT	CCC	CCC	GAC	GCC	GTC	AGA	GCC	GCC	GCG	CTC	CCA	CCC	CAG	1075
Asn	Cys	Ala	Pro	Pro	Asp	Ala	Val	Arg	Ala	Ala	Ala	Leu	Pro	Pro	Gln	
	310					315					320					
ACT	CCA	CCG	CAG	ACC	CGC	AGG	AGG	CGG	CGT	GCC	AAG	ATC	ACC	GGC	CGG	1123
Thr	Pro	Pro	Gln	Thr	Arg	Arg	Arg	Arg	Arg	Ala	Lys	Ile	Thr	Gly	Arg	
	325				330					335					340	
GAG	CGC	AAG	GCC	ATG	AGG	GTC	CTG	CCG	GTG	GTG	GTC	GGG	GCC	TTC	CTG	1171
Glu	Arg	Lys	Ala	Met	Arg	Val	Leu	Pro	Val	Val	Val	Gly	Ala	Phe	Leu	
				345					350					355		
CTG	TGC	TGG	ACG	CCC	TTC	TTC	GTG	GTG	CAC	ATC	ACG	CAG	GCG	CTG	TGT	1219

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Leu Cys Trp Thr Pro Phe Phe Val Val His Ile Thr Gln Ala Leu Cys  
 360 365 370

CCT GCC TGC TCC GTG CCC CCG CGG CTG GTC AGC GCC GTC ACC TGG CTG 1267  
 Pro Ala Cys Ser Val Pro Pro Arg Leu Val Ser Ala Val Thr Trp Leu  
 375 380 385

GGC TAC GTC AAC AGC GCC CTC ACC CCC GTC ATC TAC ACT GTC TTC AAC 1315  
 Gly Tyr Val Asn Ser Ala Leu Thr Pro Val Ile Tyr Thr Val Phe Asn  
 390 395 400

GCC GAG TTC CGC AAC GTC TTC CGC AAG GCC CTG CGT GCC TGC TGC TGAGCCGG1370  
 Ala Glu Phe Arg Asn Val Phe Arg Lys Ala Leu Arg Ala Cys Cys  
 405 410 415 420

ACCCCCGGAC GCCCCCCGGC CTGATGGCCA GGCCTCAGGG ACCAAGGAGA TGGGGAGGGC 1430

GCTTTTGTAC GTTAATTAAA CAAATTCCTT CCCAAA 1466

(2) INFORMATION FOR SEQ ID NO: 20:

- (i) SEQUENCE CHARACTERISTICS:
  - (A) LENGTH: 419 amino acids
  - (B) TYPE: amino acid
  - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 20:

Met Gly Asn Arg Ser Thr Ala Asp Ala Asp Gly Leu Leu Ala Gly Arg  
 1 5 10 15

Gly Arg Ala Ala Gly Ala Ser Ala Gly Ala Ser Ala Gly Leu Ala Gly  
 20 25 30

Gln Gly Ala Ala Ala Leu Val Gly Gly Val Leu Leu Ile Gly Ala Val  
 35 40 45

Leu Ala Gly Asn Ser Leu Val Cys Val Ser Val Ala Thr Glu Arg Ala  
 50 55 60

Leu Gln Thr Pro Thr Asn Ser Phe Ile Val Ser Leu Ala Ala Ala Asp  
 65 70 75 80

Leu Leu Leu Ala Leu Leu Val Leu Pro Leu Phe Val Tyr Ser Glu Val  
 85 90 95

Gln Gly Gly Ala Trp Leu Leu Ser Pro Arg Leu Cys Asp Ala Leu Met  
 100 105 110

Ala Met Asp Val Met Leu Cys Thr Ala Ser Ile Phe Asn Leu Cys Ala  
 115 120 125

Ile Ser Val Asp Arg Phe Val Ala Val Ala Val Pro Leu Arg Tyr Asn  
 130 135 140

Arg Gln Gly Gly Ser Arg Arg Gln Leu Leu Leu Ile Gly Ala Thr Trp  
 145 150 155 160

Leu Leu Ser Ala Ala Val Ala Ala Pro Val Leu Cys Gly Leu Asn Asp  
 165 170 175

Val Arg Gly Arg Asp Pro Ala Val Cys Arg Leu Glu Asp Arg Asp Tyr  
 180 185 190

Val Val Tyr Ser Ser Val Cys Ser Phe Phe Leu Pro Cys Pro Leu Met  
 195 200 205

Leu Leu Leu Tyr Trp Ala Thr Phe Arg Gly Leu Gln Arg Trp Glu Val  
 210 215 220

Ala Arg Arg Ala Lys Leu His Gly Arg Ala Pro Arg Arg Pro Ser Gly  
 225 230 235 240

Pro Gly Pro Pro Ser Pro Thr Pro Pro Ala Pro Arg Leu Pro Gln Asp  
 245 250 255



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Pro Cys Gly Pro Asp Cys Ala Pro Pro Ala Pro Gly Leu Pro Arg Gly  
 260 265 270

Pro Cys Gly Pro Asp Cys Ala Pro Ala Ala Pro Ser Leu Pro Gln Asp  
 275 280 285

Pro Cys Gly Pro Asp Cys Ala Pro Pro Ala Pro Gly Leu Pro Pro Asp  
 290 295 300

Pro Cys Gly Ser Asn Cys Ala Pro Pro Asp Ala Val Arg Ala Ala Ala  
 305 310 315 320

Leu Pro Pro Gln Thr Pro Pro Gln Thr Arg Arg Arg Arg Arg Ala Lys  
 325 330 335

Ile Thr Gly Arg Glu Arg Lys Ala Met Arg Val Leu Pro Val Val Val  
 340 345 350

Gly Ala Phe Leu Leu Cys Trp Thr Pro Phe Phe Val Val His Ile Thr  
 355 360 365

Gln Ala Leu Cys Pro Ala Cys Ser Val Pro Pro Arg Leu Val Ser Ala  
 370 375 380

Val Thr Trp Leu Gly Tyr Val Asn Ser Ala Leu Thr Pro Val Ile Tyr  
 385 390 395 400

Thr Val Phe Asn Ala Glu Phe Arg Asn Val Phe Arg Lys Ala Leu Arg  
 405 410 415

Ala Cys Cys

(2) INFORMATION FOR SEQ ID NO: 21:

- (i) SEQUENCE CHARACTERISTICS:
  - (A) LENGTH: 1610 base pairs
  - (B) TYPE: nucleic acid
  - (C) STRANDEDNESS: single
  - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

- (ix) FEATURE:
  - (A) NAME/KEY: 5'UTR
  - (B) LOCATION: 1..103

- (ix) FEATURE:
  - (A) NAME/KEY: 3'UTR
  - (B) LOCATION: 1508..1610

- (ix) FEATURE:
  - (A) NAME/KEY: CDS
  - (B) LOCATION: 104..1507

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 21:

CGGGGGCGGG ACCAGGGTCC GGCCGGGGCG TGCCCCCGGG GAGGGACTCC CCGGCTTGCC 60

CCCCGGCGTT GTCCGCGGTG CTCAGCGCCC GCCCGGGCGC GCC ATG GGG AAC CGC 115  
 Met Gly Asn Arg  
 1

AGC ACC GCG GAC GCG GAC GGG CTG CTG GCT GGG CGC GGG CGG GCC GCG 163  
 Ser Thr Ala Asp Ala Asp Gly Leu Leu Ala Gly Arg Gly Arg Ala Ala  
 5 10 15 20

GGG GCA TCT GCG GGG GCA TCT GCG GGG CTG GCT GGG CAG GGC GCG GCG 211  
 Gly Ala Ser Ala Gly Ala Ser Ala Gly Leu Ala Gly Gln Gly Ala Ala  
 25 30 35

GCG CTG GTG GGG GGC GTG CTG CTC ATC GGC GCG GTG CTC GCG GGG AAC 259  
 Ala Leu Val Gly Gly Val Leu Leu Ile Gly Ala Val Leu Ala Gly Asn  
 40 45 50

TCG CTC GTG TGC GTG AGC GTG GCC ACC GAG CGC GCC CTG CAG ACG CCC 307  
 Ser Leu Val Cys Val Ser Val Ala Thr Glu Arg Ala Leu Gln Thr Pro  
 55 60 65

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ACC	AAC	TCC	TTC	ATC	GTG	AGC	CTG	GCG	GCC	GCC	GAC	CTC	CTC	CTC	GCT	355
Thr	Asn	Ser	Phe	Ile	Val	Ser	Leu	Ala	Ala	Ala	Asp	Leu	Leu	Leu	Ala	
	70					75					80					
CTC	CTG	GTG	CTG	CCG	CTC	TTC	GTC	TAC	TCC	GAG	GTC	CAG	GGT	GGC	GCG	403
Leu	Leu	Val	Leu	Pro	Leu	Phe	Val	Tyr	Ser	Glu	Val	Gln	Gly	Gly	Ala	
	85				90					95					100	
TGG	CTG	CTG	AGC	CCC	CGC	CTG	TGC	GAC	GCC	CTC	ATG	GCC	ATG	GAC	GTC	451
Trp	Leu	Leu	Ser	Pro	Arg	Leu	Cys	Asp	Ala	Leu	Met	Ala	Met	Asp	Val	
				105					110					115		
ATG	CTG	TGC	ACC	GCC	TCC	ATC	TTC	AAC	CTG	TGC	GCC	ATC	AGC	GTG	GAC	499
Met	Leu	Cys	Thr	Ala	Ser	Ile	Phe	Asn	Leu	Cys	Ala	Ile	Ser	Val	Asp	
			120					125					130			
AGG	TTC	GTG	GCC	GTG	GCC	GTG	CCG	CTG	CGC	TAC	AAC	CGG	CAG	GGT	GGG	547
Arg	Phe	Val	Ala	Val	Ala	Val	Pro	Leu	Arg	Tyr	Asn	Arg	Gln	Gly	Gly	
		135					140					145				
AGC	CGC	CGG	CAG	CTG	CTG	CTC	ATC	GGC	GCC	ACG	TGG	CTG	CTG	TCC	GCG	595
Ser	Arg	Arg	Gln	Leu	Leu	Leu	Ile	Gly	Ala	Thr	Trp	Leu	Leu	Ser	Ala	
		150				155					160					
GCG	GTG	GCG	GCG	CCC	GTA	CTG	TGC	GGC	CTC	AAC	GAC	GTG	CGC	GGC	CGC	643
Ala	Val	Ala	Ala	Pro	Val	Leu	Cys	Gly	Leu	Asn	Asp	Val	Arg	Gly	Arg	
					170					175					180	
GAC	CCC	GCC	GTG	TGC	CGC	CTG	GAG	GAC	CGC	GAC	TAC	GTG	GTC	TAC	TCG	691
Asp	Pro	Ala	Val	Cys	Arg	Leu	Glu	Asp	Arg	Asp	Tyr	Val	Val	Tyr	Ser	
				185				190						195		
TCC	GTG	TGC	TCC	TTC	TTC	CTA	CCC	TGC	CCG	CTC	ATG	CTG	CTG	CTG	TAC	739
Ser	Val	Cys	Ser	Phe	Phe	Leu	Pro	Cys	Pro	Leu	Met	Leu	Leu	Leu	Tyr	
				200				205						210		
TGG	GCC	ACG	TTC	CGC	GGC	CTG	CAG	CGC	TGG	GAG	GTG	GCA	CGT	CGC	GCC	787
Trp	Ala	Thr	Phe	Arg	Gly	Leu	Gln	Arg	Trp	Glu	Val	Ala	Arg	Arg	Ala	
		215					220					225				
AAG	CTG	CAC	GGC	CGC	GCG	CCC	CGC	CGA	CCC	AGC	GGC	CCT	GGC	CCG	CCT	835
Lys	Leu	His	Gly	Arg	Ala	Pro	Arg	Arg	Pro	Ser	Gly	Pro	Gly	Pro	Pro	
	230					235					240					
TCC	CCC	ACG	CCA	CCC	GCG	CCC	CGC	CTC	CCC	CAG	GAC	CCC	TGC	GGC	CCC	883
Ser	Pro	Thr	Pro	Pro	Ala	Pro	Arg	Leu	Pro	Gln	Asp	Pro	Cys	Gly	Pro	
					250					255					260	
GAC	TGT	GCG	CCC	CCC	GCG	CCC	GGC	CTT	CCC	CGG	GGT	CCC	TGC	GGC	CCC	931
Asp	Cys	Ala	Pro	Pro	Ala	Pro	Gly	Leu	Pro	Arg	Gly	Pro	Cys	Gly	Pro	
				265					270					275		
GAC	TGT	GCG	CCC	GCC	GCG	CCC	GGC	CTC	CCC	CCG	GAC	CCC	TGC	GGC	CCC	979
Asp	Cys	Ala	Pro	Ala	Ala	Pro	Gly	Leu	Pro	Pro	Asp	Pro	Cys	Gly	Pro	
				280				285					290			
GAC	TGT	GCG	CCC	CCC	GCG	CCC	GGC	CTC	CCC	CAG	GAC	CCC	TGC	GGC	CCC	1027
Asp	Cys	Ala	Pro	Pro	Ala	Pro	Gly	Leu	Pro	Gln	Asp	Pro	Cys	Gly	Pro	
		295					300					305				
GAC	TGT	GCG	CCC	CCC	GCG	CCC	GGC	CTT	CCC	CGG	GGT	CCC	TGC	GGC	CCC	1075
Asp	Cys	Ala	Pro	Pro	Ala	Pro	Gly	Leu	Pro	Arg	Gly	Pro	Cys	Gly	Pro	
		310				315					320					
GAC	TGT	GCG	CCC	CCC	GCG	CCC	GGC	CTC	CCC	CAG	GAC	CCC	TGC	GGC	CCC	1123
Asp	Cys	Ala	Pro	Pro	Ala	Pro	Gly	Leu	Pro	Gln	Asp	Pro	Cys	Gly	Pro	
					330					335					340	
GAC	TGT	GCG	CCC	CCC	GCG	CCC	GGC	CTC	CCC	CCG	GAC	CCC	TGC	GGC	TCC	1171
Asp	Cys	Ala	Pro	Pro	Ala	Pro	Gly	Leu	Pro	Pro	Asp	Pro	Cys	Gly	Ser	
				345					350					355		
AAC	TGT	GCT	CCC	CCC	GAC	GCC	GTC	AGA	GCC	GCC	GCG	CTC	CCA	CCC	CAG	1219
Asn	Cys	Ala	Pro	Pro	Asp	Ala	Val	Arg	Ala	Ala	Ala	Leu	Pro	Pro	Gln	
			360					365					370			
ACT	CCA	CCG	CAG	ACC	CGC	AGG	AGG	CGG	CGT	GCC	AAG	ATC	ACC	GGC	CGG	1267
Thr	Pro	Pro	Gln	Thr	Arg	Arg	Arg	Arg	Arg	Ala	Lys	Ile	Thr	Gly	Arg	
		375					380					385				

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GAG CGC AAG GCC ATG AGG GTC CTG CCG GTG GTG GTC GGG GCC TTC CTG 1315  
 Glu Arg Lys Ala Met Arg Val Leu Pro Val Val Val Gly Ala Phe Leu  
 390 395 400

CTG TGC TGG ACG CCC TTC TTC GTG GTG CAC ATC ACG CAG GCG CTG TGT 1363  
 Leu Cys Trp Thr Pro Phe Phe Val Val His Ile Thr Gln Ala Leu Cys  
 405 410 415 420

CCT GCC TGC TCC GTG CCC CCG CGG CTG GTC AGC GCC GTC ACC TGG CTG 1411  
 Pro Ala Cys Ser Val Pro Pro Arg Leu Val Ser Ala Val Thr Trp Leu  
 425 430 435

GGC TAC GTC AAC AGC GCC CTC ACC CCC GTC ATC TAC ACT GTC TTC AAC 1459  
 Gly Tyr Val Asn Ser Ala Leu Thr Pro Val Ile Tyr Thr Val Phe Asn  
 440 445 450

GCC GAG TTC CGC AAC GTC TTC CGC AAG GCC CTG CGT GCC TGC TGC TGAGCCGG1514  
 Ala Glu Phe Arg Asn Val Phe Arg Lys Ala Leu Arg Ala Cys Cys  
 455 460 465

ACCCCCGGAC GCCCCCCGGC CTGATGGCCA GGCCTCAGGG ACCAAGGAGA TGGGGAGGGC 1574

GCTTTTGTAC GTTAATTAAA CAAATTCCTT CCCAAA 1610

(2) INFORMATION FOR SEQ ID NO: 22:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 467 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 22:

Met Gly Asn Arg Ser Thr Ala Asp Ala Asp Gly Leu Leu Ala Gly Arg  
 1 5 10 15

Gly Arg Ala Ala Gly Ala Ser Ala Gly Ala Ser Ala Gly Leu Ala Gly  
 20 25 30

Gln Gly Ala Ala Ala Leu Val Gly Gly Val Leu Leu Ile Gly Ala Val  
 35 40 45

Leu Ala Gly Asn Ser Leu Val Cys Val Ser Val Ala Thr Glu Arg Ala  
 50 55 60

Leu Gln Thr Pro Thr Asn Ser Phe Ile Val Ser Leu Ala Ala Ala Asp  
 65 70 75 80

Leu Leu Leu Ala Leu Leu Val Leu Pro Leu Phe Val Tyr Ser Glu Val  
 85 90 95

Gln Gly Gly Ala Trp Leu Leu Ser Pro Arg Leu Cys Asp Ala Leu Met  
 100 105 110

Ala Met Asp Val Met Leu Cys Thr Ala Ser Ile Phe Asn Leu Cys Ala  
 115 120 125

Ile Ser Val Asp Arg Phe Val Ala Val Ala Val Pro Leu Arg Tyr Asn  
 130 135 140

Arg Gln Gly Gly Ser Arg Arg Gln Leu Leu Leu Ile Gly Ala Thr Trp  
 145 150 155 160

Leu Leu Ser Ala Ala Val Ala Ala Pro Val Leu Cys Gly Leu Asn Asp  
 165 170 175

Val Arg Gly Arg Asp Pro Ala Val Cys Arg Leu Glu Asp Arg Asp Tyr  
 180 185 190

Val Val Tyr Ser Ser Val Cys Ser Phe Phe Leu Pro Cys Pro Leu Met  
 195 200 205

Leu Leu Leu Tyr Trp Ala Thr Phe Arg Gly Leu Gln Arg Trp Glu Val  
 210 215 220



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Ala Arg Arg Ala Lys Leu His Gly Arg Ala Pro Arg Arg Pro Ser Gly  
 225 230 235 240

Pro Gly Pro Pro Ser Pro Thr Pro Pro Ala Pro Arg Leu Pro Gln Asp  
 245 250 255

Pro Cys Gly Pro Asp Cys Ala Pro Pro Ala Pro Gly Leu Pro Arg Gly  
 260 265 270

Pro Cys Gly Pro Asp Cys Ala Pro Ala Ala Pro Gly Leu Pro Pro Asp  
 275 280 285

Pro Cys Gly Pro Asp Cys Ala Pro Pro Ala Pro Gly Leu Pro Gln Asp  
 290 295 300

Pro Cys Gly Pro Asp Cys Ala Pro Pro Ala Pro Gly Leu Pro Arg Gly  
 305 310 315 320

Pro Cys Gly Pro Asp Cys Ala Pro Pro Ala Pro Gly Leu Pro Gln Asp  
 325 330 335

Pro Cys Gly Pro Asp Cys Ala Pro Pro Ala Pro Gly Leu Pro Pro Asp  
 340 345 350

Pro Cys Gly Ser Asn Cys Ala Pro Pro Asp Ala Val Arg Ala Ala Ala  
 355 360 365

Leu Pro Pro Gln Thr Pro Pro Gln Thr Arg Arg Arg Arg Arg Ala Lys  
 370 375 380

Ile Thr Gly Arg Glu Arg Lys Ala Met Arg Val Leu Pro Val Val Val  
 385 390 395 400

Gly Ala Phe Leu Leu Cys Trp Thr Pro Phe Phe Val Val His Ile Thr  
 405 410 415

Gln Ala Leu Cys Pro Ala Cys Ser Val Pro Pro Arg Leu Val Ser Ala  
 420 425 430

Val Thr Trp Leu Gly Tyr Val Asn Ser Ala Leu Thr Pro Val Ile Tyr  
 435 440 445

Thr Val Phe Asn Ala Glu Phe Arg Asn Val Phe Arg Lys Ala Leu Arg  
 450 455 460

Ala Cys Cys  
 465

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What is claimed is:

1. An isolated nucleic acid encoding a human dopamine receptor that hybridizes to a nucleic acid probe selected from the group consisting of probes having a nucleotide sequence identified by SEQ ID NOS. 1, 5, 8, 10, 12, 15, 19, 19 or 21 at a temperature of 42° C. in a solution of 5X SSC, 50% formamide, 5X Denhardt's solution, 0.1% sodium pyrophosphate, 1% SDS, and 100 μmg/mL denatured salmon sperm DNA.
2. An isolated nucleic acid according to claim 1 wherein hybridization is detected after washing in a solution of 0.2× SSC/0.1% SDS at 65° C.
3. An isolated nucleic acid encoding a human dopamine receptor that hybridizes to a nucleic acid probe selected from

the group consisting of probes encoding a repeated amino acid sequence comprising from 1 to 8 copies of the amino acid sequence: (Pro/Ala).Ala.Pro.(Arg/Gly).Leu.Pro.(Gln/Arg/Pro).(Asp/Gly).Pro.Cys.Gly.(Pro/Ser).(Asp/Asn).Cys.Ala.Pro of SEQ ID NO. 20 at a temperature of 37° C. in a solution of 5X SSC, 25% formamide, 5X Denhardt's solution, 0.1% sodium pyrophosphate, 1% SDS, and 100 μg/mL denatured salmon sperm DNA.

4. An isolated nucleic acid according to claim 3 wherein hybridization is detected after washing in a solution of 2× SSC/0.1% SDS at 55° C.

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